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TRANSACTIONS

of the

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They should be legibly written on foolscap paper, on one side only, with a margin on the left side.

Illustrations, when necessary, should be drawn on the dull side of tracing linen to as small a scale as is consistent with distinctness. They should not be more than ten inches in height and *in no case* should any one figure exceed this height. Black ink only should be used, and all lines, lettering, etc., must be clear and distinct.

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All communications must be forwarded to the Secretary of the Society from whom any further information may be obtained.

The attention of Members is called to By-Laws 46 and 47.

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Wm. P. Anderson

Electrical Section.

President, R. B. Owens; Vice-President, R. A. Ross.

A meeting was held Thursday, January 7, 1904, Dr. R. B. Owens in the chair.

A paper was read by D. S. Barlow, A. M. Can. Soc. C. E., on "Comparative Cost of Electric and Steam Power from the Point of View of the User."

Mechanical Section.

President, K. W. Blackwell; Vice-President, A. W. Robinson.

A Meeting was held Thursday, Jan. 14, 1904, the President of the Section in the chair.

The following paper was read:—

PAPER No. 199

THE DREDGING FLEET OF MONTREAL HARBOUR.

By H. A. Bayfield, A. M. Can. Soc. C. E.

To fully describe the working part or details of operation of the various machines comprising a dredging fleet is, of course, beyond the limits of this paper and therefore the writer will only touch upon such points as he deems of common interest among dredge men.

The Harbour Commissioners' Dredging Fleet proper at present consists of four dipper dredges, five floating derricks, one drill boat, five tugs and twenty-three scows. There are other machines, but as the work done by them cannot be said to pertain to dredging, no particular mention will be made of them. It may be stated, however, that the complete fleet comprises forty-one vessels.

The work performed is for the most part confined to dredging in localities where deeper water is desired, the material dredged being utilized in the construction of piers, wharves and other harbour improvements.

The dredges deposit their material on scows which are unloaded by the floating derricks at points where filling is needed.

With the exception of one dredge and one derrick, the fleet works day and night, offsetting to a certain extent, the disadvantages of a short season. The total number of men employed in operating the

fleet is 220 during the warm weather, but a slight increase in the force takes place in the late autumn owing to the extra labour necessary when lines are frozen and decks coated with ice. In another portion of this paper, mention is made of the number of hands required to work each vessel and also the duties assigned to individuals.

The dredges are all of the dipper or spoon type, their principal dimensions being as follows: Length of hull 90 ft., width of hull 36 ft., maximum depth of hold from 9′ 6″ to 10′ 9″ according to dredge; size of main engine 16″ x 18″ double cylinder.

Each dredge has three spuds, two at the bow and one at the stern. The bow spuds are each operated by two wire ropes, one for lifting and one for pinning up, the former passing around a sheave located in the spud near its lower end and the latter over a similar sheave held in a casting at the upper end. The lifting and pinning up wires lead to the same drum, one coming in while the other comes off. The forward spud drums are operated by the main engine, clutches and brakes being provided for throwing in and out of gear or holding the drums stationary. The stern spud is raised by a wire rope attached near the lower end, no spud sheaves or pinning up arrangement being used. The wire passes to a drum driven by an engine which also actuates the deck capstans. This spud passes through an aperature in the stern deck and is held in position by rollers carried in yokes, one at the deck line and the other at the top of the spud slides. The upper yoke is directly secured to the piston rod of a long stroke steam cylinder, thereby affording means of moving ahead when the bow spuds are lifted.

The dipper is lifted by means of a single wire rope passing to a spirally grooved drum. The diameter of the drum varies in such a manner that the wire comes in slowly while the bucket is in the cut with an increase of speed when the dipper is clear of the material being dredged. The drum is driven by two cast steel spur gears which engage or disengage with the drum by means of a pair of belt frictions operated by a toggle joint mechanism and a steam thrust cylinder.

The dipper handles used are of the split type and are built of Douglas fir encased on all sides by steel plates, the plating being secured by Lowmoor iron rivets which pass through the wood from plate to plate. A heavy steel casting with lugs to receive the bucket connections, is bolted to each side of the handle at its lower end.

The handle is gripped or allowed to slide, as the case may be by means of a steam piston and a combination of fibre-covered plates which bear upon the sides of the handles as well as upon four long plates secured to the inner surfaces of the split portion of the arm.

Rivets are snap-headed wherever possible, but unfortunately their use is very restricted on account of the necessity of having a smooth surface where the handle passes through the friction trunnion box.

Several designs of steel bucket arms have been tried, but as the rivetting gave continual trouble they have been discarded in favour of those of combined wood and steel construction. The latter are comparatively easy to repair and give good satisfaction generally.

The total weight of a handle as described above is about 26,600 lbs. There is no doubt whatever that a solid dipper arm would prove much more durable than one split for the greater portion of its length, but its use is hardly possible with a single hoisting wire.

The standard bucket is of seven cubic yards capacity, and is built with a curved lip and front. There are also a few straight lipped dippers of five and a quarter yards capacity, but though specially designed for dredging very hard material they have proved not at all superior to the larger bucket and are, therefore, used only for work in a strong current where swinging is difficult with the dipper of large size, or when filling boxes which the seven yard bucket would overload. The body or shell of both sizes of dippers is of steel plate, with butt joints and single cover strap. The lip and lower band are of cast steel and are rivetted to the shell, rivetting being countersunk on the inside to insure a smooth surface. The door is composed of a single piece of inch and a quarter steel plate rivetted to a cast steel hinge piece. The latching device is on the toggle joint principle, and, considering the extremely severe usage it is subjected to, gives good satisfaction. Bails are a single steel casting, secured to the hoisting wire socket a cast steel shackle. The shackle takes up considerable room, but its use is necessary to prevent injury to the wire by sharp bending at the point where it enters the socket.

Each dipper carries four teeth which are of cast steel with chisel points. The teeth are made hook shaped, the hook fitting over the lip at places where projecting lugs are provided to prevent side play. The lower end of each tooth is secured to the shell by four bolts. With this arrangement of fastening, a change of teeth can be effected in about half an hour.

Several attempts have been made to design a dipper tooth that will last a reasonable length of time in hard digging. Detachable points of hardened steel were experimented with but proved a failure through lack of strength either in the point itself, or in the body of the tooth which had to be cut away to receive it.

Silver steel tips were V welded into the teeth and given a trial in rock digging. It was found that when the points were tempered

sufficiently to wear well, they were brittle and broke too frequently to warrant their use.

At present the only effort being made to improve the lasting qualities is confined to heating and dipping the tooth point after it is drawn out under the hammer.

The life of a set of teeth will of course depend upon the nature of the material being dredged. In unblasted grey rock seven hours continuous work is a fair average as shown by records kept by the writer. Upon becoming too blunt to hold well, the points are again hammered out, but there is a limit to the drawing out process and the tooth soon goes to the scrap pile.

During last season the four dredges of the fleet used up 181 teeth, each tooth having been in service at least four times.

The weights of the several parts of a seven yard dipper are as follows:—

Cast steel lip..	2,510	lbs.
Cast steel bottom band..	3,230	"
Cast steel bail..	1,335	"
Door, complete, with latch..	2,230	"
Shell..	1,500	"
Cast steel shackle..	125	"
Rivets, pins, etc...	605	"
Four cast steel teeth..	1,800	"
Total weight of bucket..	13,335	"

Considerable trouble has been experienced on account of the very rapid wear of the faces of the latching dogs, even though they have until very recently been made of mangenese steel. Castings of common steel with faces hardened as much as possible are now being tried and though the duration of the test will not allow of a decision as to the wearing qualities, it is certain that they withstand shocks and blows far better than those of mangenese steel.

Experiments are in progress to determine the advisability of annealing all steel castings used in the construction of buckets and clams. There is no doubt that the initial strain in some of these castings is very high, as its presence is frequently denoted by shrinkage cracks. It is hoped that annealing will relieve more or less of this tension and materially increase the life of the piece.

With regard to rivetting, it has been proved that rivets driven by pneumatic tools are superior to those put in by hand. The drift pin seems unavoidable in work of this kind, but it is certain that were all holes drilled fair and good, slack rivets and broken castings would not be so common.

Taking the spud record of the last three seasons, it has been found that the average life of a thirty-six inch by thirty-six inch (36" x 36") dredge spud is 5.7 months, working day and night. It must be remembered that the dredges have been working for the greater proportion of the time in rock and hardpan at a depth of water ranging from 30 to 40 feet. Examination of the broken spuds has shown that in most cases the failure was due to the giving way of the outer fibres of the stick under tensile stress. A few spuds however, have failed by a longitudinal shear along the grain.

Two dredges are now being fitted with forward spuds 42" x 42" and it is hoped that they will prove more satisfactory as regards length of service.

The boom is built entirely of steel and is supported at its outer end by two parts of a wire rope which passes around a revolving cap on a pivot at the apex of the A frame. The A frame is of wood, its lower extremity resting upon the top of the forward spud slides. It is guyed by wire cables extending aft to the lower members of the hog frames.

Three of the dredges have wooden hulls, but the latest machine is built of steel.

A dredge crew is composed of one engineer, one assistant engineer, one cranesman, one fireman, and four deckmen. The engineer has charge of the whole machine and is responsible for its operation generally. He handles the levers controlling the main engines, capstan engines, spud drums and stern spud moving ahead gear. The assistant looks after the machinery and sees that lubricators and oil cups are filled and in proper working order. He also relieves the engineer when the latter has for any reason to leave the operating dredge. The cranesman stands on a small platform secured to the side of the boom and manipulates the levers controlling the swinging engine, backing drum and dipper handle compression cylinder. The fireman tends the boiler and when opportunity permits, is supposed to help the assistant when oiling. The deckmen handle lines and do general work about the dredge.

A night shift is identical with the day crew but has in addition a watchman whose duties are to scour floors and decks, wipe down the machinery and keep the dredge throughout as clean as possible.

Dredges 2, 3 and 4 are equipped with Clyde boilers, while No. 1 dredge has a boiler of the locomotive type.

Four of the floating derricks are equipped with clam shells of approximately four cubic yards capacity. The clam shells unload soft material exceedingly well and also give good satisfaction when handling rock provided it is fairly well broken. In the latter class of work the clams are fitted with cast steel teeth which can be attached or detached in a few minutes time. The remaining der-

rick has tackle for handling four yard boxes which are used almost exclusively for rock work. The boxes are arranged closely together on scows and the dredges load directly into them, care being taken not to overload or cover up the iron work provided for attaching the derrick hoisting and tripping chains.

The principal dimensions of a derrick are as follows:—Length of hull, 76 ft.; width of hull, 27 ft.; maximum depth of hull, 7′ 6″ to 8′ 0″ according to derrick; size of main engine 12″ x 14″ double cylinder.

The boom is 80 feet long and is swung by a turn table working on a pivot casting fastened to the forward deck

The spud arrangement is similar to that of the dredges, namely, two at bow and one at stern. Spuds are operated by wire ropes as in the dredges, but the method of braking or holding spuds in one positicn varies. In derricks 5 and 6 the spuds are equipped with chains which run on rollers held in castings at the top of the spud. One end of the chain is secured to one side of the spud slides, while the other end passes through a clamping device bolted to the opposite side of the slide. When the derrick is pinned up, the clamps grip the chain and carry the load. Derrick No. 4 has a wire instead of the chain. In derricks 1 and 3 the arrangement is identical with that of the dredges. The weight is carried by the top wire, the drums being held stationary by brakes.

The original spuds used were 21″ square but as they have not proved durable, they aro being replaced by spuds 21″ x 27″.

The main engine has two grooved drums, one for the hoisting wire and the other for the tripping wire. Both drums are fitted with ordinary cone driving frictions which are thrown in or out of gear by steam thrust cylinders secured to the drum shaft and revolving with them. Drums are checked by brake straps operated by foot levers.

Two derricks have steel hog frames and back legs, but the others are of wood throughout.

A derrick day crew is composed of one engineer, one assistant, one fireman and four deckhands. The night crew is the same but with an additional hand as watchman. The engineer is in charge of the shift. The assistant works with the engineer in the operating cabin, the fireman doing the necessary oiling besides firing. The deckhands tend the lines.

As before stated, five tugs are in operation. Two of them are of steel construction while the others are of wood.

The "Robert Mackay," the larger of the two steel boats, was built by Messrs. Carrière & Lainé, of Quebec, and delivered to the Harbour Commissioners in the fall of 1901. Her principal dimensions are as follows:—

HULL.

Length over all..	81′ 9″
Length between perpendiculars..	71′ 0″
Moulded beam..	16′ 10″
Draught with full coal bunkers, about..	11′ 0″

ENGINE. (Fore and Aft Compound.)

Diameter of high pressure cylinder..	16″
Diameter of low pressure cylinder..	32″
Stroke of pistons..	24″

The high pressure cylinder is fitted with piston valve, while the low pressure has a double ported balance slide valve.

When running at 125 revolutions per minute the engine indicates about 440 horsepower.

The engine is equipped with a steam reversing gear actuated by a steam cylinder fastened to the bed plate. It is quick in its action and is so constructed that the links can be held in any position which feature is of value when a variation of cut off is desired.

BOILER.

(Water leg firebox, return tubular. Two D flues leading to a single combustion chamber.)

Length over all	12′ 0″
Diameter of shell..	8′ 9″
Area of fire grate..	43 sq. ft.
Total heating surface..	1402 sq. ft.
Ratio of H. S. to area of fire grate..	32.6
Ratio of fire grate area to area through tubes..	6

It may be stated that this boiler is an excellent steamer, and, considering the exceptionally heavy towing the boat does, the coal consumption is not high. A table showing the coal consumed by the various vessels of the fleet is given below, though it must be borne in mind that the fuel burned by a tug depends greatly upon the conditions under which the boat is working, and that as these conditions vary from day to day, it is difficult to more than average the quantity of coal used per stated interval. The quality of the coal is also a varying factof.

Steering is done by means of a steam steering gear operated by a direct steam cylinder fitted with a single piston secured to the centre of a rod which passes through both cylinder heads, the rods being attached to the tiller rope. A controlling lever in the pilot house moves a specially constructed valve gear admitting steam to

either side of the piston as may be desired. The apparatus is so designed that the piston follows the motion of the steering lever, ceasing to move when the lever becomes stationary. The whole arrangement has proved very efficient and convenient, especially for quick work when handling scows in confined spaces. Owing to the rapid action of this steering gear upon the rudder, it is an easy matter to cause the boat to roll and advantage is taken of this feature when the tug is breaking heavy ice. Without the rolling movement, five inches of green ice will stall the boat, but nine inches can be broken with engines at full speed and the rudder moving from side to side as fast as the tug will roll it.

On the 28th of November last, the writer received orders to proceed to Cascade Point and render all possible assistance to the light ship "Lurcher" which was on her way to the Atlantic. The "Robert Mackay", having already quite a reputation for freeing ice-bound vessels, was chosen as being most suitable. While passing through the Lachine Canal several miles of six inch ice were steamed through, and with the exception of a diminished speed, no difficulty was experienced. On reaching the Lake St. Louis end of the canal, it was found that lolly had accumulated and frozen to a thickness of about nine inches. The progress at this point was slow, but at no time did the tug become stalled. It will doubtless be remembered that several tugs and their tows were frozen in the canal at the time. To them the arrival of the "Mackay" meant a great deal for they were able to proceed to their destinations with very little further trouble.

The presence of floating timber and other obstacles renders the use of the sectional propeller a necessity, and all the tugs of the fleet are equipped with wheels of this style. Broken blades are a frequent occurence, but the replacing of a blade or even a whole set, is a small matter when compared with fitting a solid wheel. The propellor blades of the "Robert Mackay" are of cast steel, while the other tugs have cast iron blades. Except when breaking ice, the use of steel for this purpose is of doubtful merit, on account of the great danger of injury to the tail shaft and shoe if the blades do not give way on striking a heavy object. Another objection to their use is the difficulty of securing castings with smooth surfaces.

While dealing with the subject of tug boats, it may be stated that ease and accuracy of handling is an essential feature in a tug which is to render efficient service in a crowded waterway. The steersman should not be forced to exercise his full muscular strength when moving his wheel, nor should the movement of the rudder be so slow as to allow an undue length of time to elapse before the boat alters her course. The engineer should not have to wrestle with a ponderous reverse lever or unbalanced throttle, and above all

he should not be cursed with an engine liable to stick on the centre. A steam steerer will enable the tug captain to perform quicker and better work and the engineer can respond to his bells with certainty and despatch when his engine is fitted with steam reversing gear, properly designed throttle and a two cylinder fore and aft engine with cranks at ninety degrees.

The single cylinder engine of large size is exceedingly difficult to handle if even a moderate amount of exhaust lap is given to the valve, and, in the opinion of the writer, should never be installed unless first cost or lack of space forbids the adoption of a fore and aft double engine with ninety degree cranks. The double engine with cranks at one hundred and eighty degrees is, of course, as bad as regards sticking on the centre, and unless handled with great care by a skilful engineer, is bound to give trouble sooner or later.

Except when working in the St. Mary's current, the water available for boiler feed is generally of a muddy character and much trouble is experienced by the rapid accumulation of a muddy deposit in the boilers. Frequent blowing off and examination is imperative, the frequency of doing so depending upon the style of boiler and the locality in which the vessel is working.

Ordinary vertical boilers, unless the tubes are set in well separated rows, without staggering, have given much trouble from this course and cracked crown sheets are not uncommon. With pure water they give fair satisfaction, but when using feed heavily charged with impurities, their use is not advisable. With this type of boiler, and in all boilers for that matter, numerous washout plugs should be provided, not scattered promiscuously about the shell but so located that every portion of the boiler liable to become foul can be reached by scraper and water jet.

In the locomotive firebox type, the crown sheet offers a good lodging place for mud and especially is this the case when girder stays are used. Radial stay bolts and a curved crown will do much to prevent the accumulation of mud.

The Clyde and Fitzgibbon boilers have proved the easiest to maintain in this respect, though the combustion chamber crown sheets of both these types require careful attention.

In certain parts of the harbour, the water is so impure that it causes foaming, and water tanks filled outside the Mackay Pier have to be kept alongside the vessel, hose connections leading to the injector or feed pump.

Boiler compounds have been experimented with, but to no great extent, as the first attempts in this direction developed leaks owing to the loosening of scale which probably had been acting as a seam filler for a greater or lesser length of time.

Although the rate of coal consumption varies considerably from

month to month, a statement showing the average fuel burned may be of interest.

Type of Vessel.	Size of Main Engine.	Coal per month per vessel.	Remarks.
Dredge.....	16″ x 18″ two cyls. simple non-cond.	106 tons Double Shift.	Av. of 3 dreds. for 6 months.
Floating Derrick	12″ x 14″ two cyls. simple non-cond.	53 tons Double Shift.	Av. of 4 dks. for 6 months.
Tug.....	16″ & 32″ x 24″ Compound cond.	160 tons Double Shift.	Av. of 2 tugs for 6 months.
Tug.....	20″ x 22″ simple non-cond.	90 tons Double Shift.	Av. of 1 tug for 3 months.
Tug.....	16″ x 18″ simple non-cond.	37 tons Single Shift.	Av. of 1 tug for 6 months.
Tug.....	9″ x 10″ simple non-cond.	12 tons Single Shift.	Av. of 1 tug for 6 months.

The above quantities of coal include that consumed in keeping fires banked on Sundays and holidays. It may also be stated that the compound tugs were doing heavy work in St. Mary's current. The other tugs were chiefly occupied in general towing about the harbour.

An important item of expense in the maintenance of the fleet is that of lubrication. During last season the oil consumption was as follows:—Cylinder oil, 1,610 galls.; engine oil 517 gals.; castor oil, 4,070 lbs.; tallow 1,196 lbs.; cup grease 537 lbs.; crude petroleum 177 galls.

Average Quantity of Lubricants Used per Month, per Vessel.

Vessel.	Gal. Cyl. Oil.	Gal. Eng. Oil.	Lbs. Castor Oil.	Lbs. Tallow.	Lbs. Cup Gr'se.	Gal. Crude Petrol'm.
Dredge..	16.7	7.4	9.4	18.5	12.4	3.7
Derrick..	8.0	6.3				1.5
Tug 16″ & 32″ x 24″ comp. cond.	23.4		184.0	49.2		
Tug 20″ x 22″, simple non-cond.	6.0		93.0	12.0		
Tug 16″ x 18″ simple non-cond...	7.0		41.6	5.6	3.7	

Castor oil is deservedly a favorite among tug runners, though its cost is high compared to that of a medium grade engine oil. There is a great difference of opinion regarding the respective merits of castor and mineral oil for tug engines, but trials have shown the former to be more satisfactory and its use is now general on the tug boats of the fleet.

Referring to the table of lubricants used during last season, it will be remarked that the consumption of tallow was large. In explanation of this, however, the writer wishes to state that unfor-fortunately a quantity of very low grade cylinder oil had been purchased and to render it fit for use a large proportion of tallow had to be added. The injurious effect of tallow upon a steam engine is too well known to require comment, but unless carefully watched the average tug engineer will use it, the amount used generally depending upon how much is given him. The judicious use of properly prepared graphite with cylinder oil is to be recommended.

There is no doubt whatever that a dredge equipped only with sight feed lubricators wastes much cylinder oil. The actual work of the machinery is more or less intermittant and unless the engineer shuts off the supply, oil will continue to flow into the cylinders after the engine has stopped. As there are usually several engines on a dredge, this source of waste becomes a serious matter if economy of working is to be considered. Mechanically operated oil pumps were experimented with last season and they proved so satisfactory that they are to be fitted to all the engines of the entire fleet. Being actuated by the engine itself, they feed only when the engine is running. They are positive in their action, and if of correct design, require little or no attention beyond filling. It is claimed by some engineers that this type of lubricator will clog if graphite is used with the oil, but the writer has experienced no trouble in this direction even when using a mixture composed of one part of Dixon's Flake Graphite to eight of oil.

The subject of the durability of wire ropes is full of interest to any one concerned in the efficient and steady operation of a dredging fleet.

In nearly every case, the design of a dredge or floating derrick will not allow of the correct diameter of sheave being used for any particular wire. Take spud wires as an example. The spuds of a dredge are 36″ square, and as it is necessary that the cable lie close to the sides of the spuds, the diameter of the sheaves cannot be much greater than 36″ on the tread. If, for this purpose, we use a two inch wire composed of wires 0.1 inches diameter, we find that the stress induced by the bending alone amounts to 83,000 lbs. per square inch, which is far too high for durability. Again in the case of a dredge hoisting wire, a two and a quarter inch cable composed of

wires 0.134 inches diameter running over a six foot sheave, gives us a stress of 55,000 lbs. per square inch in the metal.

However, we are for practical reasons obliged to use sheaves of comparatively small diameter and so must make the best of it. Too much care, however, cannot be taken to so design running rigging that the same portion of a wire rope will pass over as few sheaves as possible, because the bending not only induces the undesirable stress above referred to but produces fatigue of the metal by repetition.

The correct size of wire to use for a certain purpose is often determined by trial. An instance of this may be given as follows: The floating derricks were originally equipped with 1¼″ swinging wires running over 15½″ sheaves to a turntable of 9′ 6″ diameter. These ropes have been replaced by others of 1″ diameter and results show a marked increase in the life of the rope.

Referring to the matter of spud wires, the writer suggests that the rope be not confined to two parts of large diameter over one sheave, but that the load be carried by four or more parts running over several sheaves. By using such an arrangement, the size of the rope could be greatly decreased and be more suitable to the sheaves, which would, of course, be of the maximum diameter permitted by the dimensions of the spud. There are mechanical difficulties to be reckoned with, but they are not insurmountable. Apart from the wire rope point of view a desirable feature of this arrangement would be the lowering of the pull on the hauling part of the cable when pinning up. Spud drums could be less massive than at present, though perhaps not much smaller on account of the increased length of wire to be accomodated. All running rigging should be properly lubricated with black oil or some substances suitable for the purpose. Wire rope manufacturers recommend a mixture composed of linseed oil and lamp black or Spanish brown.

When sockets are to be babbitted to the end of a wire cable, the material of the rope should be sufficiently soft to allow of bending the wires to a small radius without cracking. A socket splice is never too strong for the work it is called upon to do, and the swell on the rope end should be large enough to prevent any possibility of pulling through even if the babbitt was not present. If many wires break in bending over, we lose to a more or less extent this highly desirable feature. Of course, the babbitt cements the whole bulb together and adds materially to the strength of the splice. Possibly exception may be taken to the statement that the cable should have a swelled end, and perhaps not without reason for some wire rope manufacturers advise against the practice. The observations of the writer, however, are to the effect that a heavily loaded

wire rope will gradually pull through the socket if a substantial swell is not made on the rope end. Unless the socket is of great length a thin ring or tube of babbitt generally comes with the wire, showing that the shearing strength of the alloy is not sufficient to withstand the load.

Break downs to the machinery and other gear are frequent, due probably as much to the prevalence of the double shift system as to the over straining or mishandling of the machines. However, on account of our short season and the large amount of work to be done, day and night crews are obligatory, even though they certainly are not satisfactory from a maintenance point of view.

In the case of a dredging fleet, where to a great extent one machine works in conjunction with another, and a breakdown to the one will in all probability delay the other, it is absolutely necessary to have means whereby quick and efficient repairs can be made. To effect quick repairs, material and spares must be in readiness, and when possible parts of machines should be made to templates so that no time will be lost in fitting them to their places. By efficient repairs are meant repairs that will stay repaired or done in as perfect a manner as circumstances will permit. Good workmen, and good workmen only, should be employed, for a cheap man is generally a dear man when time, mistakes and poor workmanship are reckoned up. A few cents an hour more in an employee's pay are insignificant when a dredge and its derrick are waiting on a tug which is out of business with, say, a broken piston ring. Hire good men, give them good tools and material best suited to the job in hand and the time lost will be a minimum.

The Harbour Commissioners, until a couple of years ago, maintained a floating shop, the hull of which had long done service as an elevator dredge. Now, however, a fairly equipped machine shop on the Mackay Pier attends to all repairs.

Frequently the person in charge of a dredging fleet has to decide as to whether or not a certain repair is absolutely necessary, and before giving his decision he must consider the probable effect if repairs are not made. Will there be danger to life or limb if complete breakdown should occur ? Will the trouble extend or cause other apparatus to carry undue stresses ? Are the conditions at the time favourable for stopping a machine or would a short delay prove more advantageous ? It is often a nice point to render a decision upon, but it is best to err on the safe side. First, consider the safety of the men; second, the machine ; and, last of all, the work.

The cause of a breakdown should always be investigated, and, if possible, means taken to prevent a repetition of the failure. At this point it may be mentioned that due regard should be paid to the

fact that it is very desirable that a comparatively unimportant part should break when the load it carries reaches a certain figure, which should be well before parts of greater importance become overloaded.

Owing to the excessive and complicated straining action of a dredge, it is difficult to design its component parts so that the whole is of uniform strength, and especially is this the case in dredges with wooden hulls. A certain amount of flexibility is no doubt a good point, but this flexibility should never be so great as to cause certain members to bear stresses which properly belong to others. In a wooden dredge it is next to impossible to keep shafting or clutches in alignment and to remedy this evil all bearings should be provided with adjusting wedges or blocks. Steam piping should be put up with frequent offsets or expansion joints.

Taking the season of 1901 as an example, the cost of operation per working day or night for the different types of vessels is as follows:—

	Repairs and Maintenance.	Fuel.	Wages of Crews.	Estimated Depreciation of Plant.	Total Cost.
7 Yd. Dipper Dredge..	$27.53	$11.05	$20.30	$ 5.85	$64.73
Floating Derrick..	10.08	5.66	16.46	2.53	34.73
Tug (16″ x 32″ x 24″ Compound)	3.00	7.35	9.24	2.27	21.86
Tug (20″ x 22″ Simple)..	2.42	4.48	8.47	* .23	15.60
Tug (16″ x 18″ Simple)	4.05	5.20	7.43	* .16	16.84

*These two tugs, having been in service for many years, are rated at a very low figure.

DISCUSSION.

Mr. F. P. Shearwood observed that the author had stated that several forms of steel dipper handles were tried, and that the only one which had proven satisfactory was the composite one, made up of four steel plates filled in with wood. He would like to hear from the author why it was that weakness in the wholly steel handles developed; if it were due to the shearing of the rivets; and, if so, if this could not be obviated by re-arranging the positions and equipments of the supports. Now that wood was becoming so scarce, and steel on the other hand, cheaper, it seemed imperative that all parts of structures requiring long and heavy members, should be made of steel. It seemed that steel could be used satisfactorily in the case of the dipper handles and spuds by re-arranging the supports to suit the steel structure and not trying to make the steel structure suit the conditions of the wooden ones. Mr. Shearwood.

Mr. Bayfield explained that when the bucket was in the cut, the handle was subjected to severe twisting strains and he attributed the loosening of the rivets in a great measure to this cause. As each portion of the old style dipper handle was a rectangular box in section with no diagonal bracing, its shape could be changed without inducing tensional stresses in the sides of the figure. Hence, deformation of the box was comparatively easy, and the constant working of the plating soon loosened the rivetting. With the combined wood and steel handle, the side and top plates were not directly secured to one another as in the box section steel handle, but merely secured to the wooden centre by long rivets passing through the wood from plates opposite one another. The wooden centre really acted as cross and diagonal bracing and had the advantage of being soft enough to allow a certain amount of play to the rivets when under stress. He thought it quite possible to design a steel dipper arm that would stand the work, but in his opinion the expense would be great, as most probably plating of a special section would be required. The composite handle was comparatively cheap to build—besides being easy to repair. Mr. Bayfield.

Mr. K. W. Blackwell said he would like to ask Mr. Bayfield whether he had noticed any ductility in Mangenese steel, and if he was in favour of it and consisted it promising. Mr. Blackwell.

Mr. Bayfield said that he had not experimented with this class of steel as to its ductility. He had found, however, that it was very hard and suitable for purposes which required a hard and fair- Mr. Bayfield.

ly strong material. He had used it so very little that he could not say to what extent it would eventually be used in the fleet.

Mr. Robinson.

Mr. A. W. Robinson said that Mr. Bayfield had given a number of interesting points in connection with the working of the Montreal Harbour plant. It was impossible to design this class of machinery from theoretical considerations alone, and this might explain the difficulties which had arisen in the design of the dipper handles referred to. It was impossible to design a dipper handle from calculated strains alone and the only thing to do was to find out the form of construction which answered best from experience. One of the reasons why steel dipper handles were difficult to make successfully was that they had not sufficient flexibility. They were split in two parts, were very long, and the strain in all directions on it was very great.

There was another point which would have struck many of the members who had visited other harbour works, and that was that the plant and outfit employed in the harbour of Montreal was unlike that used in any other harbour. Especially was this true in regard to the harbours of the old world. Hardly a single machine was seen in those harbours that we had in use here for performing similar work. That was due, of course, not only to the difference in the kind of work to be done, but to the difference in the mode of operation. The plant of this harbour had been gradually evolved from the early machines in use and by gradually improving and adding new devices, it had reached its present stage of efficiency.

He believed that large single wire rope dredges such as Mr. Bayfield had described, were among the earliest single wire rope dredges in use. The first one was built to the designs of Mr. John Kennedy in 1890, and since that time a number of others have been built along the same lines. Some eight or ten dredges of the same class have also been built for use on the great lakes. They have all shown that the single wire rope hoist had a comparatively short life, and Mr. Bayfield had explained to a certain extent why this was so. Notwithstanding the fact that the ropes lasted but a short time, they were considered to be more satisfactory than the chains for large and heavy work.

The method of hoising by single wire rope was now being introduced for steam shovels, and the problem here was perhaps more difficult than in the dredge, because of the difficulty of using large size sheaves.

There was another point to which the speaker referred, concerning the use of large steel ropes over small sheaves and drums, and that was that the rope wore out much faster on the sheaves than on the drums. This might seem peculiar, but a moment's reflec-

tion would show that the rope in passing over the sheave, made two bends—one going on and one going off, whereas in winding on the drum it only made one bend. Therefore, as the durability of the wire rope was in proportion to the number of bends, it would last twice as long on the drum as it would on a sheave of equal diameter— or in order to equalize the discrepancy, the designer could afford to make the drum smaller in diameter than the sheave for equal durability. Mr. Robinson.

There had recently been built a very large wire rope dredge for the New York Harbour. It was designed to dredge in fifty feet of water. The strains in such deep water were very severe indeed. In fact, as the depth of water in harbours all over the world increased, the question of the best form of dredge for deep water work was a very serious one. The dredge referred to had spuds 5 ft. x 5 ft., and the dipper handle was a single stick of timber 36" x 36" x 75 feet long, or in other words, the same size as the forward spuds in the Montreal dredges. There were two parallel hoisting ropes, one on either side of the dipper handle. For the great depths now required, the single dipper handle appeared the most satisfactory for use.

One point mentioned by the author on page No. 49 referred to the difficulty of keeping the shafting and clutches in proper alignment, and he recommended that all dredges should be provided with adjustible blocks. Mr. Robinson remarked that in his own practice he did not employ this method of construction, consisting of various shafts and bearings attached separately to a wooden frame work. It was far better to make each portion of the machinery entirely self-contained, so that if it sprung or shifted its position at all, as it was bound to do more or less, it would all go together in one piece. That difficulty was, of course, removed to a large extent in a steel hull. It was very strange that a great many of the old dredge men still preferred wooden construction—even if steel should be less expensive. It was not always a question of expense, and the speaker thought that the reason for the preference was that they did not understand the steel or its methods of repair, and the wood they had been accustomed to all their lives. With the increasing cost of timber in this country, especially oak, it was only a question of time until all constructions of this kind would be of steel.

Mr. K. W. Blackwell said that the author had contributed a very valuable paper. Any one who knew anything about dredges would appreciate the importance of all parts being strong and reliable, made from the very best material, and probably one of the most important of all the mechanical problems was that there were so many parts about it that required specially skilled labor and care in manufacturing. Mr. Blackwell.

Mr. Blackwell. The mere fact that the Montreal dredges were equipped with spuds 42 inches square, and those in New York with spuds 5 ft. square for dredging in fifty feet of water, would give any one not familiar with this class of work, an idea of what material was required to hold a dredge up to its work. He wanted to remark in conclusion that he considered it more important to keep a dredge up to its work than to put too much stress on the first cost.

At the close of the sectional meeting a business meeting was held, Mr. K. W. Blackwell in the chair, for the opening of ballots for election of members. Messrs. J. W. Heckman, K. B. Thornton, J. G. G. Kerry and W. J. Sproule, having been appointed scrutineers, declared the following elected:—

MEMBERS.

J. C. GWILLIM.
H. C. ABELL.
R. A. CHAMBERS.
E. J. FORREST.
R. D. MERSHON.

ASSOCIATE MEMBERS.

G. B. ASHCROFT.
A. BALSLEY.
H. S. BADGER.
D. C. BLAIR.
W. J. CAMP.
J. CAUSLEY.
E. H. DARLING.
F. J. MCINTOSH.
J. MURPHY.
G. E. REVELL.
D. A. ROSS.
M. H. SAMMETT.
V. H. SCHWABE.
P. H. SMITH.
W. THOMPSON.
E. T. WILKIE.

TRANSFERRED FROM THE CLASS OF ASSOCIATE MEMBER TO THAT OF MEMBER.

R. F. H. BRUCE.
H. B. WALKEM.
J. L. MORRIS.
P. WEATHERBE.

TRANSFERRED FROM CLASS OF STUDENT TO THAT OF ASSOCIATE MEMBER.

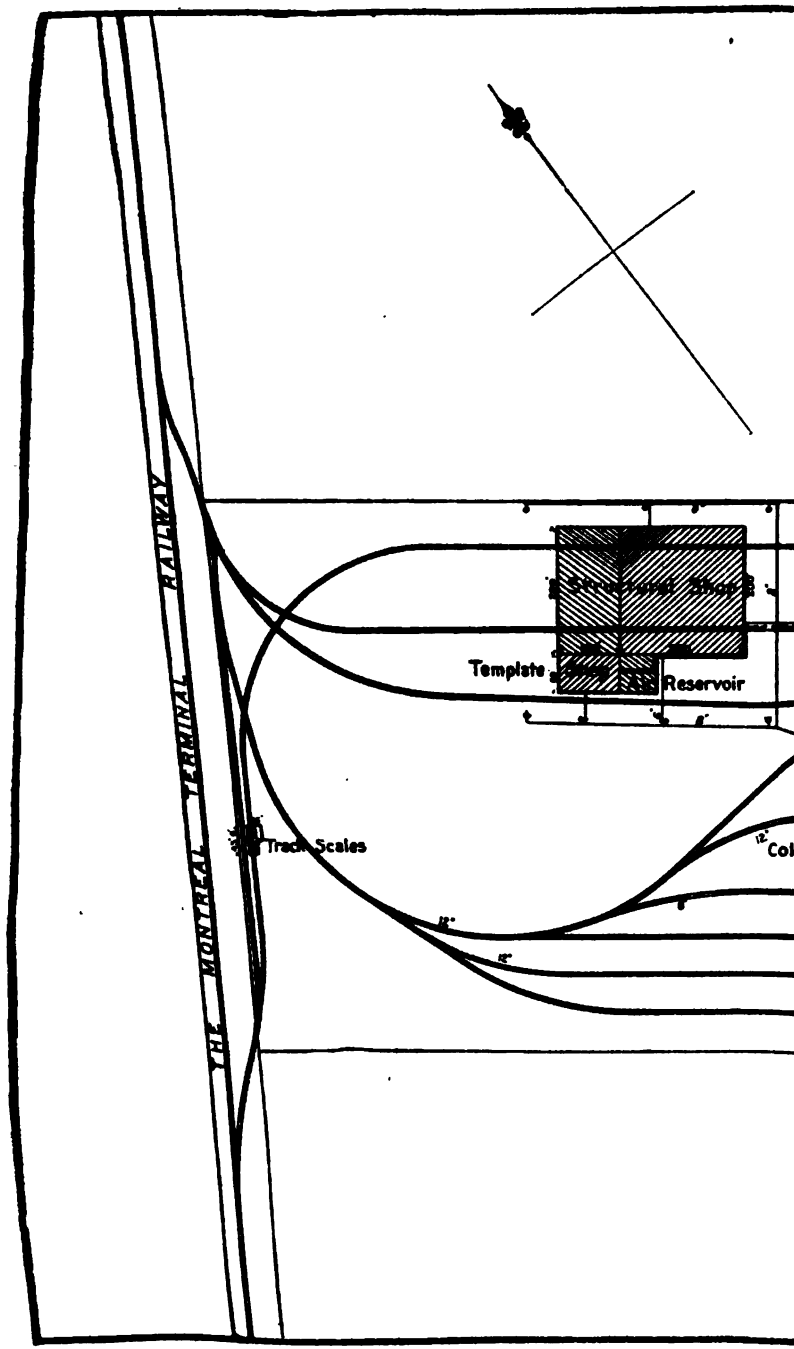
R. C. F. ALEXANDER.
G. G. GRUNDY.
J. DUCHASTEL DE MONTROUGE.

ASSOCIATES.

C. F. EICKS.
G. T. KENNEDY.
A. STANSFIELD.
F. J. GILMAN.

STUDENTS.

M. B. ATKINSON.
B. O. BAY.
C. ST. G. M. CAMPBELL.
J. M. CAMPBELL.
W. C. M. CROPPER.
W. F. DRYSDALE.
J. M. A. GARIEPY.
F. S. KAELIN.
J. D. LACHAPELLE.
G. ST. G. SPROULE.
J. A. WALLS.
S. G. F. MACDERMOT.
R. V. MORRIS.
J. E. L. O'CONNOR.
A. S. L. PEASLEE.
A. D. PORCHERON.
A. B. RITCHIE.
J. F. ROBERTSON, JUN.
G. W. SCOTT.
A. L. SHARPE.
R. F. TAYLOR.
W. L. BIRD.
A. B. BLANCHARD.
C. J. CHAPLIN.
J. H. CONGDON.
J. M. DONALDSON.
H. K. DUTCHER.
J. W. G. GREEY.
H. C. KENNEDY.
S. W. SMITH.
M. H. SULLIVAN.
G. K. MCDOUGALL.
J. MCD. MCPHEE.
D. H. NELLES.
N. W. PARKER.
H. B. POPE.
C. C. RICHARDS.
H. G. ROGERS.
J. SEARS.
G. P. SHARPE.
J. C. SMITH.
W. D. WILSON.
F. C. D. WILKES.


MONTREAL TERMINAL RAILWAY
Structural Shop
Template Shop
Reservoir
Track Scales
Cok

PHOTOGRAPH 1.

The following papers were read at the Annual Meeting, January 26, 1904:—

PAPER No. 200.

THE SHOPS OF THE LOCOMOTIVE AND MACHINE COMPANY OF MONTREAL.

By M. J. Butler, M. Can. Soc. C. E.

The Locomotive & Machine Co., of Montreal (Ltd.), was incorporated under the provision of "The Dominion Companies' Act" in 1902, with a capital of $1,000,000.00, subsequently increased to $3,000,000.00. The Company purchased the Dickson farm, lying between the Terminal Railway and the St. Lawrence River, comprising an area of 65.5 English acres, being cadastral number 21, and, also, the same parcel off the front of the Rodier Estate, lying between Notre Dame street and the river, being part of cadastral number 27, comprising an area of 2.6 English acres, all in the parish of Longue Pointe, Quebec, Canada, making a total area of 68.1 English acres, or 80.4 arpents, and having a frontage on the St. Lawrence River of 1,102 feet. The main block of land, lying north of Notre Dame street, is 860.6 feet in width. At the river bank the land lies at an elevation of some eighteen feet above the normal river level and rises with a gentle slope of one-half of one per cent. to the Terminal Railway in the rear of the property.

The soil consists of a firm, dry clay in depth from twenty to thirty feet to the rock.

The property lies within the jurisdiction of the Montreal Harbour Trust, who are building a wharf and dredging out a ship basin, large enough to receive the largest type of ship, thus giving ample facilities for ocean and river transportation.

At the rear of the property runs the Terminal Railway and the Chateauguay & Northern Railway, connecting with the Canadian Pacific Company at Hochelaga, and, via Jacques Cartier Junction, with the Grand Trunk System. It is more than probable that in a short time all railways will meet on a common line on the harbour front, thus giving a more direct access to the works.

As shown in the plan of the property there is an extensive system of tracks in the Company's property, connecting the several buildings with the river front and the railway.

The general idea of the layout of the Locomotive Works proper

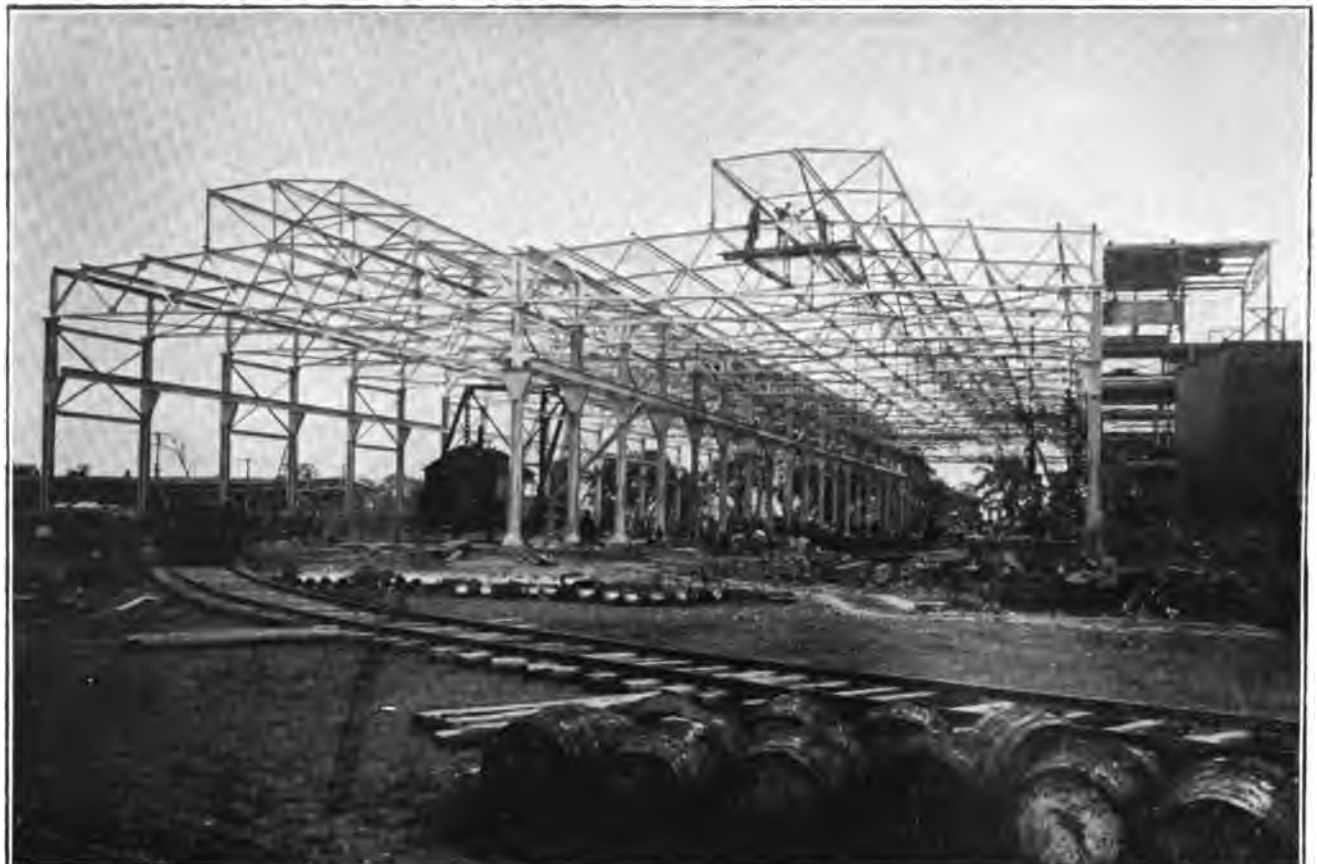
is that of the President of the Company, Mr. M. J. Haney, M. Can. Soc. C. E., and was only arrived at after long and careful study of the problems involved.

It is believed to be unique and without precedent in the various matters concerned, such as compactness and ease in handling raw material and turning it out as a finished product. The only objections raised against this style of shop have been a possible want of light and increased insurance, and both of these have been overcome; indeed, it is believed that no similar shop has been insured at a lower rate.

The Author was appointed Chief Engineer of the Company, Dec. 5th, 1902. The plans were started on the 19th of the same month, and on the 19th of January, 1903, complete bills of material were in the hands of the importers of the steel material. All pieces were specified to be cut to within ⅛ of an inch in length, it being the intention of the Company to manufacture its own structural steel work. As inquiry had shown the impossibility of securing the work in time from the existing bridge and structural manufacturing companies, during the month of February, 1903, the ground was broken for a temporary shop, built of wood, in which to install the tools required to do the work, and, in the meantime, orders were placed with the tool-makers for the several tools for delivery April 1st. The shop, 200′ x 75′, was completed early in March, but as the tools were not delivered until near the end of April, it was the 5th of May before the shop was under way, at work. On the 8th of May the building was burned to the ground. By working night and day, a line of shafting was put up in the open field, the tools were repaired, new pulleys, belts, etc., were bought, and the work started again on the 13th, the actual shut down being five days. Work was kept going with a strong force of carpenters, and, ultimately, a shed roof was built over the working spaces 80′ wide x 300′ long, but for five weeks the only covering was the sky. I may say that during the five weeks no rain fell. In this temporary shop, the entire steel structural work, comprising some two thousand tons, was manufactured and completed without further hitch, early in August. As fast as the material was manufactured it was erected, and, on the 15th day of August, when the photographs exhibited were taken, the whole of the frames, roof, trusses, etc., were erected in place.

The erection of the steel work was handled with two travelling derricks ; as a rule, about one week was required to each shop.

The Locomotive Works proper consist of five shops, viz.: A machine shop, 132 feet wide, 420 feet long, 36 feet high, divided into two bays by a centre line of columns, each bay being served with an overhead electric travelling crane of ten tons capacity, which travels



PHOTOGRAPH 2.

the entire length of the shop. A great number of fixed radial cranes serve each tool where required, thus obviating waiting for the travelling crane. A forge and smith shop 380 feet long, 66 feet wide and 36 feet high lies at right angles to the machine shop, and in line with the west of it. The several fires are served in the shop with fixed radial cranes. For travelling heavy pieces through the shop, cars are used on a centre track. Alongside of the smith shop, is the erecting shop, 380 feet long by 66 feet wide, and 49 feet high. This shop is served with two 60 ton electric travelling cranes. There is one surface track down the centre of the shop, having a shallow pit running the whole length of it. Alongside of the erecting shop is the boiler shop, 380 feet long, 66 feet wide, 36 feet high. At the south end of the boiler shop, is the rivetting tower, of the same width as the boiler shop, and forty feet in length by 75 feet high. In the tower are located the pump and accumulater, one hydraulic rivetter with 17 feet gap working under a pressure of 60, 80 and 125 tons, one hydraulic rivetter of 10 feet gap working under the pressure of 60 and 80 tons. The pump works against a pressure of 1,500 lbs. per square inch. The large rivetter is served with a 20 ton hydraulic crane for boiler work, the small one with a ten ton hydraulic crane for mud, ring and smaller work.

The boiler shop proper is served with a 20 ton electric travelling crane which traverses the entire length of the shop. Beside this, at each of the tools there is a fixed radial crane.

Alongside of the boiler shop is the foundry, 66 feet wide, 380 feet long, 36 feet high. The moulding floor occupies 40 feet in width by the entire length, and in the bay alongside is situated the cupola of 20 tons capacity. The core ovens, cleaning, chipping or the moulding floor is served with a fifteen ton electric travelling crane, as well as a number of fixed radial cranes.

The brass foundry is up a half story in the side bay, and, on the same level, is the charging floor. The charging floor is to be served with a hydro-pneumatic elevator (drop). The foregoing buildings are of structural steel framing with roof trusses of the same space. The columns generally rest on cast iron pedestals which, in turn, are supported on concrete base blocks and are spaced 20 feet centre to centre throughout. The side walls for a distance of five feet above the ground are of rubble limestone, laid up in Portland cement mortar. At each column extending from the stone work to the roof is brick pilaster four feet in width, all of which is laid up in Portland cement mortar. The space between the pilasters is largely glass, except for a band some six feet in width, which is made up of 2″ x 4″ pine studding (first dipped in Portland cement mortar), covered on both sides with expanded metal and plastered

on the outside with Portland cement mortar, and on the inside with the Imperial Plaster Company's plaster.

The partition walls between the several shops are of similar construction to the belt course.

The roof covering consists of 3″ pine and spruce ship lap plank thoroughly spiked to nailing strips of 3″ x 6″ pine, bolted to the steel purlius, covered with tar and gravel roofing. Every effort has been to insure slow burning construction and to make the buildings as nearly fireproof as possible.

The floor in the machine shop consists of 6″ of concrete resting on a layer of broken stone of an average thickness of 6″. Embedded in the concrete are 3″ x 3″ nailing strips to which the under floor of 3″ pine plank are spiked, and the whole is intended to be overlaid with 1″ hard birch flooring.

In the forge and smith shop and foundry the natural earth has been leveled off and tamped. In the boiler and erecting shops 3″ plank resting on heavy sills is overlaid with 1″ hard birch flooring.

The side lights, as shown in the side elevation and photographs, comprise a large percentage of the outer wall area. On the roof of the machine shop, two monitors 16 feet in width by 7 feet high with continuous side lights pivoted, run the full length of the shop. Similar monitors are on all the remaining shops. In the machine shop roof there are also three rows of skylights, one row in the foundry and smith shops, two rows in the erecting and boiler shops. All the glass in the sidelights is what is known as factory ribbed glass, the skylights being glazed with plain wired glass. The skylight frame in the forge and foundry are of copper, in the other shops of galvanized iron. All the flushing is of crimped galvanized iron, the cornice work of plain galvanized iron and any siding used of corrugated galvanized iron. At night an abundant supply of arc and incandescent lamps gives ample light. Particular care and study was devoted to secure ample noticed light, and the end aimed at has been attained.

The power house has a rubble stone foundation and the rubble wall is carried up four feet above the ground, the balance of the wall being of brick. The engine room is 50′ wide x 71′ long, the boiler room 50 feet wide x 80 feet long. A brick wall separates the two rooms. The roof is supported with steel trusses, these in the engine room being designed for a concentrated load of ten tons at any point in addition to the regular roof load. Those in the boiler room were designed to support the two 20 ton coal hoppers in addition to the regular roof load. The roof covering is of 3″ pine ship lap plank, covered with tar and gravel roofing.

In the boiler room the floor is of concrete, in the engine room 3" plank supported on heavy beams and overlaid with 1" hard maple flooring.

These two shops are together in a brick two-story building 66' x 112', the foundations being of rubble limestone laid up in Portland cement mortar. The stone wall is carried up to five feet above the ground level, the remainder being built of brick. The columns of 12" x 12" pine are spaced 12 feet centres one way by 22 feet the other, and rest in a cast iron shoe plate bedded in a concrete base capped with the usual cast iron pintle. The running beams consist of four pieces of 9" x 9" tamarac, ship fastened together, making a girder 18" x 18". The floors are of 2" x 4" pine nailed together and to the beams and covered with 1" hard maple and birch, making a floor 5" thick. The roof columns are of 10" x 10" pine, the foot resting directly on the cast iron pintle. The roof girders or beams are of 8" x 12" pine, the roof sheeting being of 3" ship lap plank covered with tar and gravel. Large windows in all four sides of the building glazed with factory ribbed glass give ample light. The interior is whitewashed. There is an elevator of the hydro-pneumatic type 10' x 13'. All the walls are carried above the roof about 12" and gutters lead in to down spouts inside of the building.

The pattern storage building 66' x 98', one story in height, consists of brick walls, the columns and roof sheeting, etc., being designed on the same slow burning lines.

The store house, 100' long by 36' wide, is a brick two story building with a basement and has been designed as a slow burning building, the beams, columns, floor and roof being similar to the pattern shop. At the present time the upper floor is used as a general office, drafting rooms, etc.

The structural shop as now finished is 200' wide by 200' long, although planned to be 300' in length. The height in the clear under the roof trusses is 22 feet. The roof trusses are spaced 20' centre to centre and are figured for a concentrated load of ten tons; on the outer walls they are supported upon steel columns, at the centre by a 100 feet span truss, leaving one column in the centre of the building; the lower chord of the cross trusses is continuous so that a trolley can travel the entire width of the shop. The monitor is 40' in width, 10' high, running the length of the shop, both sides of which are of glass. Skylights are provided in alternate blocks over the roof. A large percentage of the end and side walls is of glass. All the glazing in the side lights consists of factory ribbed glass, the skylights being of plain wired glass. Two material tracks, 4' 8½"

gauge, are on opposite sides of the building, the assembling track running through the centre. The side walls are of brick, the end walls of 3" plank, covered with corrugated galvanized iron. The roof sheeting is of 3" ship-lap plank, covered with tar and gravel roofing, the hip is covered with crimped galvanized iron. The floor is of 3" plank on heavy joists. Notwithstanding the width of this building, it is well lighted with natural light. The great advantage of the factory ribbed glass is the diffusion secured and the absence of concentrated beams with the attendant shadows.

There is a 9" sewer from the works to the river. All the roof drainage is conducted to the reservoir. All down pipes are inside and all gutters are back from the cornice.

The boiler equipment consists of four Babcock & Wilcox water tube boilers, fitted with superheaters of 250 H.P. each, arranged in two batteries. The boilers are equipped with the Jones automatic underfeed stokers. The draft is well taken care of with a Sturtevant induced draft plant. The boiler feed pump is an outside packed duplex plunger pump, Northey manufacture, pumping through a Laurie 500 H.P. feed water heater, using the exhaust from the auxiliary engines. Overhead are two coal hoppers each of twenty tons capacity, from which pipes will lead to the automatic stoker. The coal will be hauled up on a trestle to the top of the building in small cars, and dumped into a Jeffrey coal breaker from which it drops into the bins. (The whole of this portion of the plant has not been completed owing to the winter coming on so suddenly.)

The engine room equipment consists of one Laurie Cross Compound Corliss condensing engine of 500 H.P., belted by a 39" 3 ply leather belt to a 400 K.W. Western Electric Generator; one 75 H.P. ampere motor working off the Montreal Light, Heat and Power Co. circuit from Shawinigan Falls, coupled direct to a 60 K.W. Western Electric Generator, with all the usual switchboard accessories; one Cross Compound Steam Cross Compound Air Canadian Rand Drill Compressor of 2,000 cubic feet capacity per minute, fitted with an independent condenser with a full complement of gauges, etc.

There is also located in the building a 1,000 gallon Underwriter Fire Pump drawing its water supply from the reservoir and pumping into the protection service mains, tanks, etc. All the steam plant in the power house has been designed for a working pressure of 200 pounds to the square inch with 100° superheat.

The water supply for drinking purposes is taken from a drilled well five hundred feet in depth, and is distributed throughout the works by a steam driven deep well pump. All the roof drainage, the overflow from the condensers, hot well, etc., drains into a

PHOTOGRAPH 3.

reservoir of 300 000 gallons capacity. On the river bank is located a 750 gallon rotary pump driven by an electric motor connected to the distribution mains and the reservoir by a 6" cast iron pipe. Ordinarily it keeps the reservoir full but, in emergencies, by closing one valve and opening another, it can pump direct into the fire protection service. The 1,000 gallon pump takes its supply from the reservoir through a 12" cast iron suction line and distributes the water about the works as shown on the plan. There is also a 50,000 gallon tank, elevated on a steel tower 100 feet in height, directly connecting with the mains, upon which the sprinkler system depends for a steady supply and head. All of the shops except the structural shop and the storehouse are fully equipped with automatic sprinklers.

The Locomotive shops are heated by the Sturtevant hot blast system, using exhaust steam, supplemented with live steam. There are two fans driven by a direct connected engine. The hot air is conducted in conduits, and is so distributed as to reach the outer walls, risers being supplied in each bent, then discharging close to the floor and along the windows.

The pressure allowed on the clay under columns was not allowed to exceed three tons per square foot. The concrete pedestals were not allowed to be loaded to a greater extent than fifteen tons per square foot. Cast iron pedestals were used to distribute the load on the concrete.

The roof trusses were designed to carry a load of fifty pounds per square foot.

All the material used was of medium steel in accordance with the requirements of the manufacturers' specifications, the tests and practical working have shown a uniform tough and reliable steel. Unit stresses were kept within 16,000 lbs. per square inch, making due allowance for column-formulae and impact.

In designing the work care was taken to have as many duplicate parts as possible in order to save detailing template work and possible errors in erections. The entire work of detailing was done by two men: Messrs. Legat and Stenneken, to whom credit is due for the uniform accuracy of their work. The shop work was handled satisfactorily by Mr. Jud. Nichols. The laying out of the foundations and general field work was under the charge of W. V. Taylor, A. M. Can. Soc. C. E. The tool equipment of the various shops was bought under the supervision of Mr. R. T. Shea. Other things being equal, preference was given to Canadian manufacture and it is a source of pride to learn that the Canadian tools supplied have proven to be equal to the best.

The great bulk of the tools, however, was of necessity purchased from United States manufacturers.

PAPER No. 201.

THE ANGUS SHOPS.

Canadian Pacific Railway, Montreal.

By H. GOLDMARK, M. Can. Soc. C. E.

The "Angus Shops" are situated on the Quebec line of the Canadian Pacific Railway in Hochelaga Ward, Montreal, about two and a half miles from the Place Viger Station. The site is a plateau with an average elevation of about 127 feet above sea level.

It is very nearly level, having a general slope of about one-tenth of one per cent. towards the river. The property is a rectangular plot about 4,700 feet long and 2,000 feet wide, its longer axis running north-east and south-west.

The connection of the shop tracks with the main line of the railroad is at the north-west corner, the steep gradient of the road making any other connection impracticable. Although the contour of the ground is favorable and the necessary grading comparatively moderate in amount, much expense had to be incurred in order to procure safe foundations. This was due to the fact that the solid rock bottom is from eight to twenty feet below the ground line (except in the case of one or two shops), while the blue clay overlying the same is altogether too soft to support the foundations of the buildings. The extra expense involved in these extra foundations was nearly $80,000. In a few cases ordinary piles capped with concrete were used, but almost all the important shops are built on what may be called a dry wall foundation. For each wall a trench three to four feet wide was excavated to bed rock and filled to a level of five feet below the ground with large flat quarry stones laid dry. On this sub-foundation the ordinary masonry walls were reared.

As the ground was thoroughly saturated with water this work was expensive and tedious. It is believed, however, that on the whole this was the most economical and suitable foundation that could be used. This was especially the case as the stone for these foundations—as likewise for all rubble and concrete work—was taken from a limestone quarry on the shop grounds about one-quarter of a mile from the buildings. Near the freight car shop an outcrop of the hard trap rock, locally known as banc-rouge, involved about 8,000 cubic yards of rock excavation. It may be added that the eastern portion was wooded, and had to be cleared,

while a part of the central portion was swampy, requiring a moderate amount of gravel filling. For surface drainage several open ditches four to five feet wide were built, but these also drain territory belonging to other owners north of the shop grounds. The surface drainage of the central part of the grounds will go into the sewers, referred to later in this paper, which connect with the city system. The main purpose of the shops sewers is, however, the carrying off of wastes.

The Angus shops are intended primarily for the maintenance and repairs of the rolling stock in use on the eastern half of the Transcontinental Railway, and provision has also been made for the construction of a considerable number of new locomotives and passenger and freight cars. In addition to this a separate building is devoted to the manufacture of frogs and switches, while the machine shop and the foundry will turn out many miscellaneous articles required in operating the railway and in new construction.

The general stores are to serve the entire system, while the general offices will serve as headquarters for the superintendent of rolling stock, master car builder and the general storekeeper.

The shops naturally fall into three classes, the first, those devoted exclusively to car work; the second, to locomotive construction and repair, the third being common to both departments.

The first class comprises the planing mill and cabinet shop, the passenger car shops, freight car shop, truck shop and car machine shop, as well as the wheel foundry and the dry kilns.

Locomotive work is mainly concentrated in the large locomotive machine and erecting shop, while the blacksmith shop and grey iron foundry (with its pattern shop and storage building), serve for car work as well as engine construction.

The arrangement of the buildings with reference to one another is of the first importance, and became the subject of extended investigation. It was influenced largely by the shape of the property, and the position of the main line tracks as well as the ground available for storage. The future enlargement of the shops had also to be considered. Every building is in fact so arranged as to allow future enlargement, while suitable locations have been reserved for additional buildings. The main point to be considered in the arrangement was, however, the economical and direct handling of the material from the raw state to its incorporation into the finished car or engine. The general layout may be called a combination of the longitudinal and transverse systems. The tracks running parallel to the buildings and to the long axis of the shop grounds form the principal means of access. As may be seen by reference to the plan most of the buildings are arranged along a transverse avenue eighty feet wide. On this avenue, popularly called

the Midway, the usual transfer table is discarded in favor of a ten ton overhead electric travelling crane, running on structural steel support over 1,000 feet long. It is believed that this crane will prove a most valuable adjunct in handling material between the different shops. It is supplemented by a surface track with turntables on the Midway. A similar outdoor crane serves the stockyard adjacent to the grey iron foundry.

The different classes of work may be briefly indicated.

The building of freight cars is one of the most important functions the shops will have to fulfil. A large and increasing number are a necessity to the road, while existing facilities in Canada are meagre, and the prevailing duty makes importation from the United States expensive, besides being opposed to the policy of the railway to have all possible work done within the Dominion.

The proposed output is twenty-five to thirty cars per day, requiring in the aggregate a very large amount of lumber and iron. The large wood storage ground indicated will probably prove scanty rather than too liberal.

This lumber will all of it pass through the planing mill, though a large proportion of it must first be dried in the larger, or softwood, kiln. The finished timbers emerge from the west end of the mill and pass on to the freight car shop, a small transfer table assisting the movement. The iron work for freight cars is forged in the blacksmith shop or cast in the grey iron foundry and machined in the car machine ship, whence it goes to the truck shop or the freight car shop for final use. In the truck shop the trucks for the freight cars, as well as for the coaches, are put together. The chilled wheels are to be cast in the well-equipped wheel foundry with a capacity of three hundred wheels per day. They are bored and pressed on to the axles in the west end of the truck shop, which is provided with all necessary machinery for this purpose.

The completed truck goes to the freight car shop, where the car bodies are erected on it. There are four tracks for erection purposes, each 540 feet long, and two intermediate tracks for bringing in supplies. Six travelling cranes fitted with air hoists will handle the heavier material.

The material for the passenger car shops is prepared in the mill and the cabinet shop, the mahogany and other hardwood being dried in the smaller kiln and stored in the hardwood storage, which forms the first floor of the upholstery shop. The coach shops are served by an electric transfer table seventy-five feet long, operated through an overhead trolley by a 20 H.P. alternating current motor. The coach shops are 100 feet wide, and each shop has twenty-eight tracks spaced twenty-four feet apart centre to centre.

The locomotive shop is of the longitudinal type, with three

bays, each 1,165 feet long, of which about 300 feet is devoted to the boiler and tank work. There are three bays; the erecting bay, which is eighty feet wide, an adjacent machine shop bay, fifty feet wide, and a third bay twenty-five feet wide, with an overhead gallery of the same width to be used for lighter machinery.

In the erecting shop there are three tracks with pits and two intermediate supply tracks. The engines are handled by two sixty ton electric travelling cranes, each having a ten ton auxiliary hoist. In the boiler shop there is a twenty ton travelling crane on the same runway, and numerous jib cranes. In the machine shop there is one fifteen ton and one ten ton crane of fifty feet span. All these cranes are driven by continuous current motors, the voltage being 250. Besides this the boiler shop has a hydraulic crane in the rivetting tower to serve the riveter.

Construction of the Buildings.

In the designing of the buildings adaptation to their respective uses and economy in both first cost and maintenance were the prime considerations. It is hoped, however, that the appearance of the buildings is not objectionable, though perhaps not aesthetically pleasing. Some care was indeed taken to avoid disfiguring construction. Among the principal requirements to be met in the construction, we may mention the necessity for good lighting in all parts of the buildings and in all weathers. To ensure this the brick walls were pierced with as much window surface as appeared safe. Steel frame construction for the side walls was, however, not used, the walls being self-supported, and also carrying the trusses except in the south wall of the locomotive shop. The windows occupy about fifty per cent. of the wall surface. In addition to this, almost all the buildings have skylights; these generally run transversely, extending half the width of the building. As there is a skylight in every bay, and its width is half of the width of the bay, the skylight area is about twenty-five per cent. of the total roof area. These skylights are of galvanized iron framing and covered with three-eighth inch rough cast glass laid in putty. The panes are two feet wide, and in one piece for each half skylight, avoiding all joints in the glass. A revolving ventilator is generally fitted to each skylight.

Another important requirement was the greatest possible safety against destruction by fire consistent with reasonable economy. The buildings are all of them of a simple strong construction, in conformity with the rules for slow burning mill construction, as developed by the Massachusetts Mill Owners Mutual Insurance Companies.

The walls are of hard burned brick laid in Portland cement mortar. They are from twelve inches to sixteen inches thick, with pilasters about twenty feet apart. In the arrangement of the roof framing and the spacing of the supporting columns, the demand of the operating department with regard to the layout of the machinery had to be considered, and the result is in some cases a compromise between their requirements and economy in construction. It is believed, however, that as built no important requirement in the use of the shops has been sacrificed. The framing of the roofs is of three kinds: First, a column and girder construction (usually in timber), as in the truck shop and frog shop, the passenger car shops and the cabinet shop; secondly, a roof frame consisting of Howe trusses, supported on steel columns, as in the freight car shop, planing mill and car machine shop. It may be added that the wooden Howe trusses in the car shops were adopted, instead of steel trusses mainly to safe time. The saving in cost did not exceed twelve and a half per cent. In the outcome there was probably no saving of time from the use of timber, but on the other hand no great disadvantage resulted from using this form of construction. The heavy timber girder and post construction, as used in the truck shop, etc., was adopted as being cheaper and better than truss work, and its use is believed to be fully justified.

The principles of "mill construction" were fully carried out, the purlius in no case being less than six inches by twelve inches, and in many buildings eight inches by sixteen inches. They are spaced from eight to ten feet part. The roof boards are three inches thick in all cases. In the locomotive shop they are eleven inches wide with tongue and groove. In most of the other buildings this roofing was built up of strips of three by three, laid with broken joints in random lengths and well nailed horizontally and vertically. These strips were surfaced on three sides, but were not tongued and grooved. On top of the boards a four-ply tar and gravel roofing of standard construction was laid. There is a galvanized iron flashing around the skylight, but there are no gutters or downspouts.

The flooring throughout consists of three inch unmatched plank nailed to cedar sleepers four feet apart and bedded in from fifteen to eighteen inches of cinders.

It may be added that the roof loads were taken at 70 lbs. per square foot (total loading), and the stresses in the timber beams at 1,500 lbs. per square inch.

The structural steel is of simple construction, though every attempt was made to secure rigidity, especially where crane runways had to be supported. Tensile stresses are 15,000 lbs. per square inch on the net section, and compressile stresses 12,000 lbs. reduced for length. In the crane runway girders, the tensile stresses were reduced to 12,500 lbs. per square inch.

Heating.

The heating of the shops was the subject of an extended study in order to determine the most practicable system. This question was necessarily taken up in connection with the design of the power plant. The economy of producing power in an independent station is dependent on the utilization of the exhaust steam for heating. As exhaust steam possesses about ninty per cent. of the heat units contained in the steam before it has passed through the engines, it is clear that every consideration of economy will lead to its utilization if possible. Whether any additional boilers will be required, over and above those necessary for power, will depend, of course, on the amount of power, the size of the shops, and the prevailing temperature. In the Angus shops, about 26,000,000 cubic feet had to be heated in the various shops, while the horse power installed in the engine room of the power house is nearly 3,000. A somewhat careful calculation, based upon the prevailing practice, and a study of the temperatures in Montreal as recorded by McGill University for many years past, led to the conclusion that about 2,800 boiler horse power would be required, and that the heating requirements were very nearly the same as the power requirements under average weather conditions.

The choice lay between three systems of heating,—the hot blast or Sturtevant system; ordinary direct steam radiation, and a hot water system. In the first, exhaust and live steam are taken to one or more points in each building, and used there to heat coils of steam pipe, and also to drive a small engine operating a fan. Air is taken either from outdoors or from the inside of the building, drawn by the fan over the heating coils so as to be warmed to about 130 degrees, and then blown through ducts over or above ground to different parts of the building. This was the system finally adopted for all the buildings, though the hot water system presented some advantages. The requisite radiating surface for heating by hot water is, however, difficult to place in the buildings, and the first cost of the system is considerably greater.

In the arrangement of the pipes, care was taken to proportion them in such a way as to utilize the exhaust steam as much as possible. In extreme weather certain portions of the buildings will have to be heated by live steam by day as well as by night.

The steam pipes are carried from the power house to the several buildings in a tunnel 6′ high and 4½′ wide, built of brick. A few of the smaller mains are, however, carried under ground in wooden boxes.

Power Plant.

All power, whether for mechanical or lighting purposes, is generated in the central power plant. This contains seven 415 horse power Babcock & Wilcox boilers, 150 lbs. pressure, one

150° superheat and one Babcock & Wilcox boiler built for a pressure of 300 lbs. for testing the completed locomotive boilers in the boiler shop, a special four inch main being laid to that point.

Two "Green" economizers are used, and a Sturtevant induced draft fan and stack.

The engine and generator equipment is as follows:—Three 750 horse power Cross compound engines, non-condensing, connected to 500 K.W. alternating current generators. These have a voltage of 600, and a frequency of 7,200 alternations per minute. The speed of the units is 150 revolutions per minute. An auxilary unit of half this size, with a simple engine, is provided. These generators provide all current for lighting as well as for power, excepting that necessary for cranes and a limited number of variable speed tools. For these, two units are provided, each being a 300 horse power simple engine direct connected to a direct current generator, producing 250 volts. The speed of these engines is 180. The distribution from the power house to the different shops is by bare wire on steel poles.

As to the motor equipment in the different shops, the larger tools will have individual motors, but group driving will be used for smaller tools; the smallest motor being ten horse power.

Sewers.

The sewerage system is rather extensive, but simple in its character. Two main lines of sewers are carried transversely, connecting with the city sewer on Nolan Street. They begin with a diameter of eight inches at the northern part of the grounds, and increase to three feet by two feet. They are connected with all lavatories, etc., and also serve to a limited extent for surface drainage, which is carried to the sewers through wooden drain boxes.

Water Supply and Fire Protection.

The city provides two systems of water mains,—one for ordinary uses at a pressure of about 35 lbs., the other for fire purposes only, with a pressure of 130 lbs. per square inch. There are two entirely separate systems of mains all over the grounds for these two services. The supply system has a six inch main on the Midway, with smaller mains diverging to the different buildings. The fire service consists of a 12 inch main on the Midway, and eight inch, ten inch and twelve inch mains encircling the various buildings. About sixty three-way hydrants are placed at different points in the grounds, and are about 150 feet apart. With the fire mains is also connected the sprinkling system. About 13,000 automatic sprinklers are put in all the buildings; their arrangement being strictly in accordance with the specifications of the underwriters.

Two 1,500 gallon Underwriters' pumps are placed in the power house as auxiliary measures in connection with the fire service.

In addition to the city water supply, the shops have their own supply of water, which consists of two artesian wells six inches in diameter and 550 feet deep, sunk through the limestone rock close to the power house. It is believed that these will furnish nearly 20,000 gallons per hour of very pure water. As a further safeguard against fire, an open reservoir 66 feet in diameter, with a capacity of 500,000 U.S.A. gallons, has been provided. A 75,000 gallon steel tank, fifty feet in height, serves to maintain a uniform head on the supply pipes and gives additional storage.

The general welfare of the employees has been looked after to an unusual degree. A very complete system of lavatories is provided; the latest sanitary plumbing will be installed, and the lavatories are in every case under the same roof as the main building, thus obviating the necessity for the men to go out of doors, which in this climate is very objectionable in winter.

The system of heating also provides most excellent ventilation.

It is impossible in this brief paper to refer in detail to the machinery to be installed in the different buildings. Brief mention may, however, be made of the wheel foundry equipment. This is the well-known Whiting rectangular system, which has been worked out with great care by the Whiting Foundry Equipment Company, and it is hoped will produce car wheels very economically and of high grade. The grey iron foundry, in like manner, is to be equipped according to the latest and best practice.

The large locomotive shop is to be fitted with the latest machinery and tools, working high grade steels at the highest cutting speeds called for by proper economy.

The boiler shop, at the west end of the locomotive shop, will have a seventeen foot gap hydraulic elevator with a sixty-five foot riveting tower for holding the twenty-five ton hydraulic cranes. The pressure in the accumulator will be 1,500 lbs. per square inch.

The blacksmith shop is being equipped with oil furnaces throughout. There will be an overhead system of exhausts, and a blast system for introducing air. Shavings will be removed from the planing will and cabinet shop by the exhaust fan system, and carried to the power house for consumption under several of the boilers.

PAPER No. 202.

THE ELECTROTHERMIC PRODUCTION OF IRON AND STEEL.

By ALFRED STANSFIELD, D.Sc., A.R.S.M., A. Can. Soc. C. E.

The commercial possibility of producing iron and steel in the electric furnace is a question of considerable interest at the present time in view of the attempts which have recently been made in this direction. These attempts, which are still being continued, include the production of iron and steel by processes similar to those usually adopted, but in which the heat necessary for enabling the chemical reactions to take place and for fusing the metal and accompanying slag is furnished by means of electric power instead of by the combustion of carbonaceous fuel as at present.

At first sight this idea appears to be quite absurd in view of the high degree of efficiency already attained in the metallurgy of iron and steel, and of the much greater cost of electrical heat than of coal heat; but the fact that commercial attempts to produce iron and steel electrically have actually been undertaken shows us that it is advisable to reconsider this conclusion.

Although the electric furnace is still in its infancy and its full powers are unknown, it is quite obvious that the possibility of applying heat exactly at the required point, of producing a temperature which may be as high as that of the electric arc, and of doing this without being obliged to blow through the furnace a stream of air and other gases is one that, in certain cases, may outweigh the greater cost of electrical energy. A very high temperature can easily be produced by electrical heating in a furnace containing strongly reducing gases, and this fact has already been utilized in the production of certain alloys of iron such as ferro-chrome, ferro-tungsten, ferro-silicon, etc.,* in which cases the value of the alloys and the difficulty and expense of producing them by ordinary furnace methods has led to the use of the electric furnace in preference to cupola or crucible furnaces, in spite of the greater cost of electrical heat.

Is it possible, however, that the expensive electrical energy should ever be used commercially for the production of iron or steel, metals which are produced with ease and economy by ordinary furnace methods?

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* Keller, Journ. Iron and Steel Inst., 1903, I., p. 161.

The answer to this question must depend mainly upon the relative cost of fuel and electrical energy. There are at present no electrical iron or steel smelting furnaces equal in size to a modern blast furnace or even an open hearth furnace, so that satisfactory demonstrations of their efficiency on a large scale are still lacking, but the great efficiency of electrical heating enables us to predict with a fair degree of accuracy the amount of energy that such furnaces would require, and such calculations are supported by the working results of small furnaces already in operation.

Taking first the direct production of pig iron from the ore, Albert Keller,* of Paris, states that he has determined, experimentally, that one ton † of pig iron requires ¼ of a kilowatt year, that is 2,190 kilowatt hours for its reduction in addition to the 350 kilos. of coke needed to effect the chemical changes.

Dr. Goldschmidt ‡ in reporting on the Stassano process, which was producing nearly pure iron from the ore, calculates that the production of one metric ton of carbon free iron from a 65% ore would require, assuming an efficiency of 80%, 3,364 horse power hours, or 2,510 kilowatt hours, which is of the same order as the previous figures. In the operation of a small Stassano furnace of about 100 kilowatt's capacity a charge of 70 kilograms of ore mixture was reduced in two hours with an expenditure of electrical power equal to 121.5 kilowatt hours, or 3,945 kilowatt hours per metric ton of iron, a figure which is 57% greater than the calculation, but the discrepancy is not surprising in view of the smallness of the test.

It should be remembered that the production of one ton of pig iron would require somewhat less heat than that of one ton of carbon free iron, both on account of the smaller amount of iron to be reduced and of the lower temperature of its melting point.

In order to realize what these figures mean, we must enquire into the price to be paid for electrical energy.

The cost of electrical energy is, indeed, the most important factor in determining the possibility of the electrical smelting of iron ores. It is by no means easy to obtain satisfactory figures. One Canadian writer states that an electrical horse power can be produced hydraulically in America for 0.05 cents per hour, while the small consumers of electric light in Montreal pay 10½ cents for the same amount, a figure which is 200 times as great as the other.

The author has obtained a number of figures for the cost of production and the selling price of electrical power, and these place

* Journ. Iron and Steel Inst., 1902, vol. I., p. 170.
† Probably one metric ton or 2,205 lbs.
‡ Electro-chemical Industry, March, 1903, p. 247.

the cost of producing an electrical horse power under very favourable conditions from water power as 0.13 cents per hour, while the price at which it may be bought will be 0.16 or 0.17 cents, and in exceptionally favourable cases even lower figures may be obtained, it being understood that very large outputs are considered, that these are to be employed near the source of power and that the power is to be used continuously 24 hours a day and 365 days a year.

The problem may be considered in two ways, either as a simple iron smelting proposition in which electric power is purchased with the other supplies, or as a scheme for the utilization of a water power in which the iron smelting is merely considered as a means to that end; and the price charged for electrical power would probably be different in these two cases.

Let us suppose that the iron smelter purchases power at 0.15 cents per E.H.P. hour or 0.2 cents per kilowatt hour.

If 2,500 kilowatt hours are required for the production of 1 metric ton of pig iron the cost for electrical energy would be $5.00.

Against the cost of the electrical power may be set the cost of the fuel that is saved by using electrical heat. About 0.6 of a ton of coke is saved per ton of iron produced and this at $2.50 a ton * would amount to $1.50 per ton of iron.

Dr. Goldschmidt considers that the carbon electrodes used in the electric furnace will cost about 70 cents per ton of iron, and against this figure should be set the saving effected by the absence of blowing engines and hot blast stoves.

We may, therefore, consider that the prices of fuel and of electrical power are the main factors to be considered as determining the relative cost of the two methods of smelting iron ores. It is quite clear that electrical smelting of iron ores cannot compete with the blast furnace using coke at $2.50 a ton, even in places where very cheap water power is available, but if the price of coke were $8.00 instead of $2.50, the saving of coke and blast would about equal the cost of the electrical heat, so that in localities where furnace coke cost upwards of $8.00 a ton and where cheap water power could be obtained, it might be better to smelt iron ores electrically than by means of coke. Mr. Keller,* in his paper read before the Iron and Steel Institute, considers that in Brazil, Chile and New Zealand electrical smelting of iron ores would be possible and he quotes prices of coke in Brazil and Chile that would be prohibitive for the blast furnace smelting of iron ores, but it would be necessary also to consider at what price iron could be im-

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* Mineral Industry, vol. XI., page 135, average price at ovens in the United States during 1902.

* Loc. cit.

ported from outside sources, before deciding that electrical smelting of iron ores would be financially possible in any locality.

The above considerations apply to the smelting of iron ores that are equally suitable for the blast furnace and the electric furnace, but there are some ores such as iron sands and titaniferous iron ores which can be smelted in the blast furnace only with considerable difficulty † while in the electric furnace owing to the absence of a blast and to the higher temperature attainable less difficulty may be experienced. It is obvious that cases may occur in which the electric furnace, although more expensive when treating an ordinary iron ore may yet be less expensive than the blast furnace when treating certain refractory ores, and the possibilities of treating these ores at all may depend upon the possibility of smelting them electrically.

The possibility of the electrical smelting of charcoal iron should be considered as in this case, owing to the greater value of the product and the higher cost of the fuel there is a greater probability that electrical smelting may be commercially possible.

Leaving now the smelting of iron ores for the production of pig iron, let us consider the electric furnace methods of producing steel, including in this term both structural steel and the more valuable varieties such as crucible steel.

Mild steel can be made in the electric furnace by the direct reduction of pure iron ores, using only just enough carbon in the charge to reduce the oxide of iron to the metallic state.

Dr. Goldschmidt states that Stassano can produce, in his furnace, steel containing less than 0.1% of carbon, 0.01% of phosphorous and 0.06% of sulphur from ores containing nearly 0.06% each of phosphorous and sulphur. The amount of sulphur in the coal used in the charge is not mentioned.

As the cost of production of this steel is about the same as that of producing cast iron in the Stassano furnace, it would appear that electrically smelted steel can be obtained directly from the ore at a price that would compare with that of open hearth or Bessemer steel. For such a purpose it would probably be advisable to use particularly pure ores and coal, but as there is no need (as in the blast furnace) to have more coal or coke than is required for the reduction of the iron oxide, it might be possible to provide an excess of oxide sufficient to carry off in the slag the bulk of the phosphorous and sulphur from ordinary ores unless they were highly siliceous.

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† See, however, a paper by Rossi (Trans. Am. Inst. of Min. Eng., vol. XXXIII., 1903, p. 179), on the "Metallurgy of Titanium" in which he states that iron ores with 20% or 30% of titanic acid can be smelted with no more difficulty than iron ores containing that amount of silica, provided that the charges are suitably arranged; and that the resulting pig iron is of especially good quality.

Thus the absence of fuel in the electric furnace enables it to be used for the production of either cast iron or steel directly from the ore.

The methods usually adopted by electro-metallurgists for the production of steel resemble more closely the open-hearth and crucible processes. Cast iron, obtained electrically or in the blast furnace, is melted electrically together with steel scrap and pure iron ores, the impurities in the charge are eliminated, mainly as oxides in the slag, and a metal is obtained which may retain the desired amount of carbon, or may be recarburized by suitable additions in the furnace or the casting ladle.

The electrothermic production of steel from intermediate products such as pig iron and steel scrap with the usual additions of iron ore has been attempted by several experimenters.

Kjellin's electric induction furnace is stated to be capable of producing molten steel from cold pig iron and scrap at the rate of 1 metric ton of tool steel for 800 E.H.P. hours,* the cost for power being, in this case, about one-fourth of that incurred in the production of pig iron from the ore—that is about $1.25 per metric ton of steel.

The conditions were exceptionally favourable, as charcoal iron was used, but, on the other hand, the use of molten pig iron would have further reduced the expense for power. The steel was said to be exceptionally good and this was attributed to the absence of dissolved gases. Very little exact information is available in this connection, but it is considered that the superiority of open hearth steel over Bessemer steel and of crucible steel over open hearth steel is due, not entirely to a greater degree of freedom from the ordinary metalloids present in steel, but in part, at least, to the degree of freedom from dissolved gases, such as oxygen, nitrogen or hydrogen ; these gases being likely to be most abundant in Bessemer steel and least abundant in crucible steel.

Probably the greatest field of usefulness of the electric furnace in the metallurgy of iron and steel will be in the production of crucible steel. As it still pays to fuse this material in small amounts in crucibles, in order to protect it from the gases unavoidably present in an open hearth furnace, it seems probable that the electric furnace which can fuse steel more cheaply than the crucible process and can protect it quite as effectually from any gases that may be found objectionable, must replace the crucible furnace.

It may also be expected to partly replace the open hearth furnace, in the production, for example, of the more expensive varie-

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* This figure is an estimate of the output from a 1,000 H. P. furnace, the actual results obtained with a furnace of 200 H. P. were considerably more costly. Electro-Chemical Industry, vol. I., 1903, p. 576.

ties of steel in which the expense of fusing is of less importance than the soundness of the product.

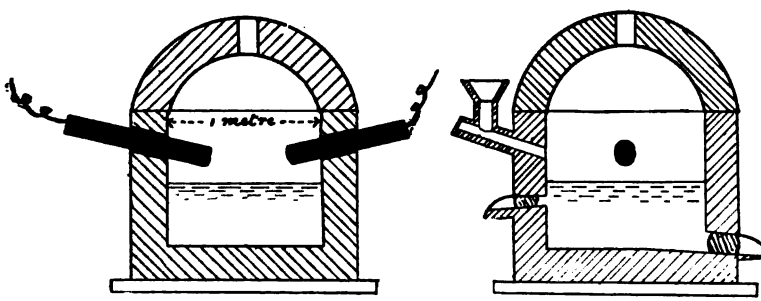
Very many different types of furnace have been used for the electro-thermic smelting of iron ores or the production of steel, but they may all be placed in one of two classes :—(1) furnaces heated by means of an electric arc and (2) furnaces heated by the passage of an electric current through the charge itself or through some poorly conducting part of the furnace.

The Stassano and Heroult furnaces are examples of arc furnaces, and the Keller, Harmet and Kjellin furnaces depend upon the heating effect of an electric current flowing through the charge itself.

A few of these furnaces will now be shortly described with the aid of diagramatic illustrations. More detailed information can be obtained from the original papers to which references are given.

The Stassano furnace is constructed of masonry and is lined with magnesite bricks. The working chamber is rectangular and is one metre square and one metre in height with an arched roof or lid.

The position of the carbon electrodes and the charging and tap-



THE STASSANO FURNACE.*

Fig. 1.

ping openings is clearly shown in figure 1, while a pipe through the lid removes the carbon monoxide resulting from the reaction.

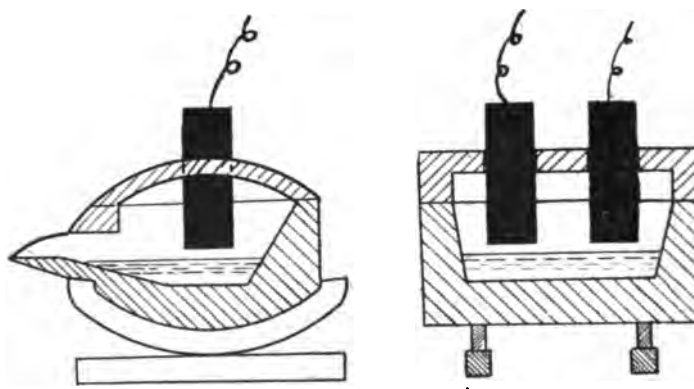
An alternating current arc is maintained between the carbons, which can be drawn apart by suitable mechanism, and the ore mixed with coal or charcoal is fed in at the side of the furnace and lies below the arc. The ore must therefore be heated by conduction and radiation from the intensely hot arc which occupies the upper part of the furnace, the method of heating being like that in the open hearth furnace.

An alternating current of 2,000 ampères at 170 volts is used in

* Electro Chemical Industry, vol. I. (1903), p. 247.

the arc which, when the furnace has become hot, traverses the whole width of the furnace and consumes about 450 horse power.

While the use of the electric arc has certain points in its favour it seems unlikely that the greatest economy can be obtained in this way. Thus, for example, the heat can only penetrate the ore by conduction through the mass and, meanwhile, heat is being lost by conduction through the upper walls of the furnace. Also the ore is not pre-heated before entering the fusion chamber, and the waste gases, by passing through the arc on their way out, tend to escape at a very high temperature, and so to waste heat which might have been employed in pre-heating the ore charge.



THE HEROULT FURNACE.*

Fig. 2.

In fact, both the pre-heating and the partial reduction of the ore might be effected by the hot carbon monoxide escaping from the furnace. The furnace was working in Italy on local iron ores and produced steel directly from the ores. Dr. Goldschmidt concluded that the steel would cost $18.80 per metric ton and that the process could not be economically introduced into Germany.

The Heroult furnace is like a tilting open hearth furnace and has two vertical carbon electrodes as shown in figure 2. The current flows from one of these into the charge of ore or metal to be melted and back on to the other carbon, thus producing two arcs between the carbons and the charge which is also heated to a certain extent by the passage of the current through the molten slag and metal.

The furnace was used at first for the direct reduction of iron

* Electro-Chemical Industry, vol. I., 1903, p. 449.

ores, but has been found to be more suitable for the production of steel from scrap and pig.

Heroult constructed a 400 H.P. furnace which took a charge of three tons but he gives no details as to the current employed.

The transmission of heat from the arc to the charge will probably be better in this furnace than in the Stassano furnace, but considerable losses of heat must take place through the holes in the roof through which the electrodes enter.

The Siemens furnace (fig. 3), has been frequently used for the reduction of metallic oxides and for melting metals. It consists

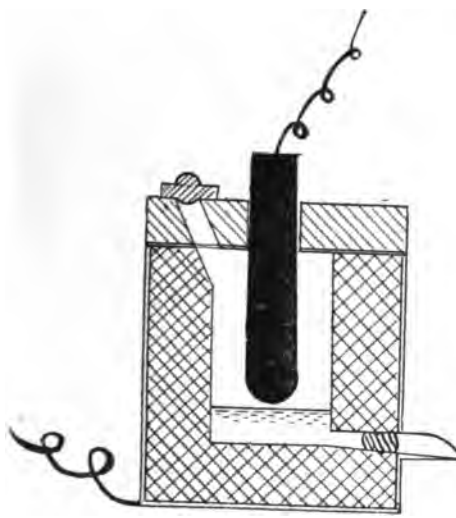


Fig. 3.

of a crucible composed wholly or in part of carbon which is connected to one of the leads, while a carbon electrode which dips into the crucible is connected to the other. An arc is formed between this electrode and the contents of the crucible, and fresh quantities of the ore can be charged in from above until the crucible is full of the molten metal and slag.

The Siemens furnace is very convenient for experimental work on the reduction of difficultly fusible metals such as chromium, tungsten, titanium, etc., and A. J. Rossi * has employed it on a larger scale for the production of ferro-titanium and similar alloys.

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* Electro-Chemical Industry, vol. I., 1903, p. 523.

The Keller furnace † for the reduction of iron ores (fig. 4), is of the resistance type. It is similar in construction to an iron blast furnace, except that the crucible of the Keller furnace is larger in section than the stack. Four carbon electrodes are inserted vertically into this enlarged crucible and dip into the slag. The current is carried by the fused slag and metal from one electrode to another and, in this way, the charge is heated. The gases resulting from the reduction of the oxides in the ore pass up through the descending column and give up their heat to the ore and also effect the reduction of a part of the iron. The molten iron and slag are tapped out at intervals in the usual manner.

The method of heating adopted in this furnace is more conducive to economy than is the heating by electric arc as in the Stassano furnace.

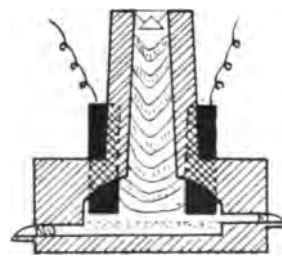


Fig. 4.

The Keller furnace, moreover, is suited to continuous introduction of fresh charges of ore while the Stassano furnace is worked intermittently, which must tend to a waste of heat. Furnaces of the resistance type are also able to supply heat more or less uniformly through a large mass of ore, and are, therefore, better suited than arc furnaces to large scale operations. In the Keller furnace, however, it seems probable that the current would be carried from one electrode to the other, largely through the molten iron in the crucible, and as this is a relatively good conductor, most of the heat would be developed in the molten slag immediately surrounding each electrode, while the middle of the furnace would tend to be cooler.

In the manufacture of steel an intermittent method of smelting must be adopted in order to adjust the composition of the steel, and such furnaces as the Stassano and Heroult would appear to be

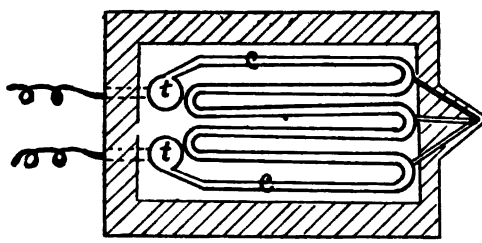
† Journ. Iron and Steel Inst., 1903, vol. I., p. 161.

suited to this, while the reduction of ore would be best effected in the Keller or similar furnaces in which continuous smelting and pre-heating of the charge is provided for.

The Harmet furnace* is similar in construction to the Keller furnace. The Keller and Harmet furnaces are employed to produce pig iron direct from the ore, and the pig iron is then tapped into a furnace of the Heroult type and converted into steel.

The Kjellin † and the Gin furnaces ‡ are remarkable because in them the heat is produced by the passage of the current through the molten metal itself, instead of through the fused slag or through the air above the charge.

In this method a difficulty arises on account of the low specific resistance of the metal, because an enormous current would be re-



GIN FURNACE (Sectional plan).
Fig. 5.

quired to heat up a bath of moderate size. Gin endeavours to overcome this difficulty by making his furnace in the form of a canal *cc* (see fig. 5), which is folded on itself and contains the metal ; the current is introduced through water cooled metallic terminals of large section *tt*.

It is intended to tap the steel from the three loops of the canal simultaneously. The canal is formed in some neutral refractory material like chrome iron ore.

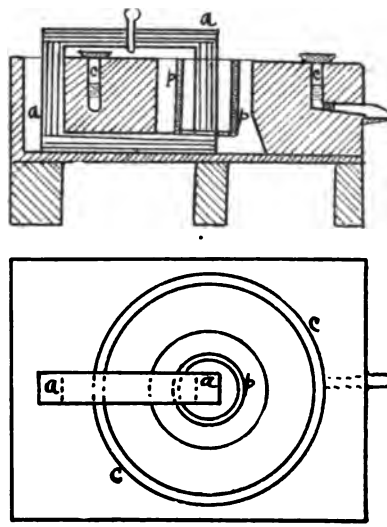
The numerous difficulties which are likely to occur in connection with the use and maintenance of such a furnace are too obvious to need mentioning, but the principle employed may, perhaps, be developed in a somewhat different form.

The Kjellin furnace (see fig. 6), consists of a circular canal *cc*, containing the metallic charge which forms the secondary winding of a transformer of which *pp* is the primary coil and *aa* the iron core. In this manner an enormous current is produced in the

* Electro-Chemical Industry, vol. I., 1903, p. 422.
† Electro-Chemical Industry, vol. I., 1903, p. 576.
‡ Electro-Chemical Industry, vol. II., 1904, p. 20.

molten metal without the necessity for any terminals to lead in the current. A furnace of this type has been successfully used for the production of steel, but the shape of the furnace would not be conducive to the production of steel of a uniform composition.

The Kjellin furnace has been used for the production of steel from pig and scrap, a certain amount of metal being left in the furnace to carry the current in the early stages of the following charge, but if molten pig iron were employed, this would be unnecessary.



KJELLIN FURNACE.

Fig. 6.

The Gin furnace is intended to be used in the same way, but is still in the experimental stage.

The electric furnace, using carbon electrodes, is especially suited to operations of a reducing character as the electrodes are then protected from loss by oxidation. In the production of steel, however, an oxidising slag is employed to remove the impurities from the pig iron, and this slag would tend to corrode the carbon electrodes and itself to become deoxidised, and, therefore, unfit to refine the iron. This difficulty is met in the Heroult furnace by keeping the electrodes above the surface of the slag, so that the current passes into the charge by means of an arc. In the Gin

furnace water cooled metal electrodes are used and in the Kjellin furnace electrodes are dispensed with altogether.

In concluding this paper, it may be worth while to consider in what way the electrothermic production of iron or steel will be likely to be of use in Canada.

The production of crucible steel in the electric furnace may be considered to be possible both technically and financially, and furnaces might be installed for the production of tool steel, which at present is largely imported, the electric current being produced by means of water power or by gas engines run by blast furnace gas.

The utilisation of titaniferous iron sands is a problem of considerable importance. These sands are difficult to smelt, partly because sandy ores are difficult to treat in the blast furnace and partly on account of the titanium, which produces a very infusible slag.

A. T. Rossi,* of New York, in a paper already referred to, furnishes evidence to show that the difficulty of smelting titaniferous ores has been very much exaggerated.

He states that blast furnaces have been run for seven years in England on ores containing 40% of titanic acid, and that iron slags containing over 30% of titanic acid have been found to be perfectly satisfactory in an experimental blast furnace at Buffalo.

In smelting such ores in the blast furnace the titanium passes almost entirely into the slag, the iron produced carrying not more than a few tenths per cent. of titanium, but even this small amount appears to decidedly improve the quality of the iron for certain purposes.

In the electric furnace more strongly reducing conditions can be obtained than in the blast furnace and it is possible to smelt a titaniferous ore so as to obtain a rich ferro-titanium, the titanium being reduced to the metallic state instead of remaining as oxide in the slag.

Rossi has added such alloys to ordinary cast iron and finds that the addition of 2% or 3% of a 10% ferro-titanium increases the strength of cast iron about 20% or 30%.

In the absence of analyses it is not possible to say whether this increased strength is due to the addition of the titanium or, for example, to some difference in the amount or condition of the carbon or other constituents of the iron, but if Mr. Rossi's conclusions are sustained it would appear probable that the electric smelting of titaniferous ores for the production of ferro-titanium may be commercially possible on a moderate scale.

The electrical smelting of these ores for ordinary pig iron has not, I believe, been attempted, and even if it were technically

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* Trans. Am. Inst. Min. Eng., vol. XXXIII., 1903, p. 179.

successful it would be difficult to produce the iron sufficiently cheaply to compete with blast furnace iron.

Dr. Stansfield's paper was illustrated by lantern slides of the electric furnaces referred to and was followed by a demonstration of the melting of metals in a Siemens furnace and a Moissan furnace; the last named being similar in construction to the Stassano furnace, and being furnished with a lens and mirror, by means of which a picture of the inside of the furnace was projected upon a screen so that the audience was able to watch the metals melting down in the intense heat of the electric arc.

In the Moissan furnace direct currents are usually employed, and the electric arc is forced down upon the metals to be melted by the influence of an electro-magnet placed near the furnace. The principle of the resistance type of electric furnace was demonstrated by means of a pencil of carbon, about 6 inches long and ¼ inch diameter, which was raised to a dazzling white heat by the passage of the current.

ELECTRICAL SECTION.

A meeting was held Thursday, Feb. 18, 1904, Dr. R. B. Owens in the chair. The following paper was read:—

PAPER No. 203

METHODS OF CALCULATING STORAGE BATTERY INSTALLATIONS.

By W. E. WINSHIP, Ph.D.

It is not the purpose of the present paper to take up in detail all the points which come up in the calculation of a storage battery installation; we shall confine ourselves more particularly to the determination of the proper size of a battery, both as to capacity and number of cells, under specified conditions.

The question of the chemical behaviour of the lead storage battery, which is practically the only form which is commercially used for work of any magnitude, is of importance principally to the student and the manufacturer. The theory of the lead accumulator can hardly be said to be in satisfactory shape, as it is by no means determined exactly what chemical reactions take place on either charge or discharge. This state of affairs is remarkable for an electrical appliance which has been so long known and practically used, and, while it would certainly be desirable to have a complete understanding of all the phenomena which take place, the difficulties of analysis of the lead compounds under the conditions existing in use and the state of development of the theory of electro-chemistry make it improbable that we can expect such a theory in the near future. We do know, however, the physical properties of storage batteries sufficiently well to enable us to calculate them for practical purposes.

The batteries in general use in America are the "Chloride" and "Gould." The "Willard" battery has also found some application, and there are several which are now appearing on the market which are more or less like the "Tudor" battery of Germany. These types are too well known to require a detailed description, and the curves given below will apply to all of them to a greater or less degree. We may, however, distinguish between those in which the plates have an extremely large surface exposed to the acid solution and those where the exposed surface is relatively small; the capacity and efficiency in the former case is materially greater at high rates of discharge than with the latter.

The capacity of a storage battery in ampere hours depends on the rate of discharge, and is usually assumed as 100% at the 8 hour, 87½% at the 5 hour, 75% at the 3 hour and 50% at the 1 hour rate

of discharge. With the large surface plates, batteries usually are rated very conservatively at the 1 hour rate and have very little excess capacity at the 8 hour rate of discharge, while with the other types the reverse is true.

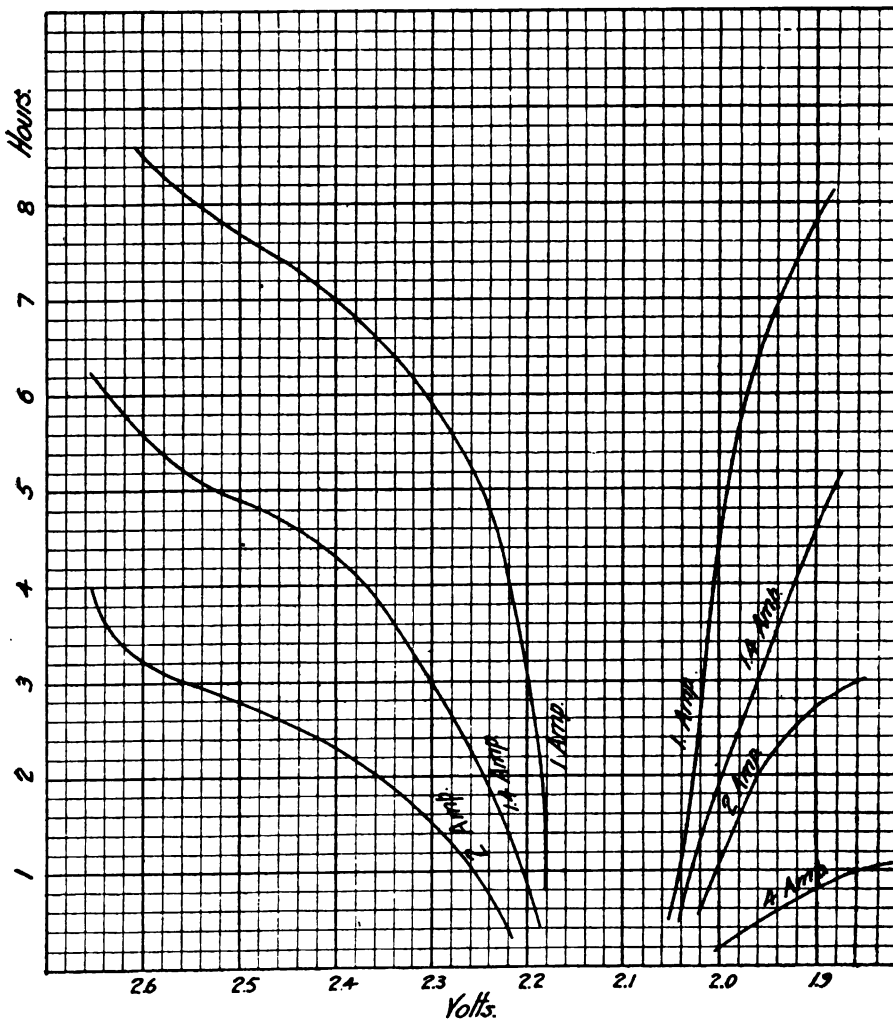


Fig. 1.

In Fig. 1 are shown the variations of potential difference on continuous discharge and charge as a function of the time. These

curves, and also those below, are reduced to a unit basis, and are for a cell which has a capacity of one ampere for eight hours or four amperes for one hour. By multiplying "amperes" in these curves by the ratio of the capacity of a cell in ampere hours at the eight hour rate of discharge, divided by eight, these curves apply to various sizes of the same type. The point where discharge is cut off is somewhat arbitrary, but is fixed by the consideration that if the E.M.F. drops off beyond a certain limit the efficiency of the battery becomes too low. It should be noticed that by saying the capacity of a battery is only 50% of that at the eight-hour rate of discharge when it is discharged in one hour, we do not mean that we must charge twice as many ampere hours as are taken out on discharge, but rather, if more than 50% of the capacity of the battery in ampere hours at the eight-hour rate is taken out in one hour, the E.M.F. would fall too low for the battery to continue to show a good efficiency. In charging we have to furnish only very little more than is taken out, as the ampere hour efficiency of a storage battery is extremely good, being 95% to 98%, provided the charge does not occur at too high a rate.

The net efficiency (watt hour output ÷ watt hour input) of stationary types of commercial batteries, over a complete cycle of continuous charge or discharge, of long duration, is not much more than 87% at the best, and ordinary commercial results where the discharge rate is high are from 70% to 75%. If the battery is called on to cover short cycles of charge and discharge, as is often the case in railway and similar installations, where the fluctuations are short but violent, and the battery discharges and charges the difference between the instantaneous and average loads, the efficiency is much higher. It may be very approximately 90%, and tests over a year's time under operating conditions have shown as high as 85%.

In storage battery problems it is usual to distinguish between two classes of work they are called on to do: (a) discharges to cover what may be called long peaks, as distinguished from sudden variations, or fluctuations, the battery being charged when the external demand is light and thus equalizing the load on the generating units so as to increase their load factor; (b) causing the battery to charge and discharge according to the external load to absorb the instantaneous fluctuations and reduce the generator load to the average, or in some cases, a combination of these two. The calculation of an installation in these two cases is quite different.

In determining the size of a storage battery, a prominent consideration is the maximum rate at which it may be economically worked as this determines to a certain extent the amount of its depreciation with time. This depreciation may be roughly separ-

ated into two factors: one which is dependent on time and independent of the amount of work which the battery does, and one which varies with this work. In Europe it has been the practice to install much larger batteries than with us in America, and there is considerable to said in favour of the larger installation; its efficiency is somewhat better, and the emergency value of a battery, a very important consideration, is in proportion to its capacity. In America batteries cost materially more, however, and a consideration of interest and depreciation point to the smaller plant. It may be stated that American practice, as a result of experience, is to work a battery at the hour rate on fluctuations which occur frequently, while infrequent heavy peaks may be covered at double this rate. In general the size of a battery will be determined by two considerations: What is the minimum discharge capacity which will safely do the work demanded, and what importance attaches to the value of the battery as an emergency factor? In most cases this latter consideration is a very important one, since with railway or lighting corporations the reliability of service which a battery offers is of prime importance. In any practical problem the peculiar conditions will govern very largely the determination of the installation.

It has been pointed out that the capacity of a battery varies with the discharge rate. The load on a generating station is seldom steady and if we wish to cover a peak by a battery discharge, the rate of this discharge will, in general, vary continuously. We must then be able to determine the requisite capacity of a battery to cover such a peak.

In Fig. 2 the curve Y represents the ampere hour capacity of a unit cell at various rates of discharge. The curve Y′ represents the current which would discharge the battery in the time T; X and X′ are the corresponding curves for what may be termed an ideal battery, that is, one whose capacity does not vary with the discharge rate. We shall use these curves in the determination of

THE CAPACITY OF A BATTERY TO COVER A PEAK.

Let us suppose that it is required to know what capacity a battery should have to cover a peak as shown in Fig. 3. For our purposes this peak may be reduced to the figure ABCD as its approximate equivalent, or again to AEG+BCHF, where BG is parallel to CD and BF,EG and CH are perpendicular to AD.

The curve X′ is represented by the equation:—

(1) $i' = X/t$.

It may be shown that the curve Y′ will be very closely approximated throughout the range of practical application by the equation

(2) $i-b = K\ /(t-a)$

where $a = -3/4$, $b = X/32$ and $K = X.\ 105/128$. We may translate the actual discharge into that of an ideal battery (having a con-

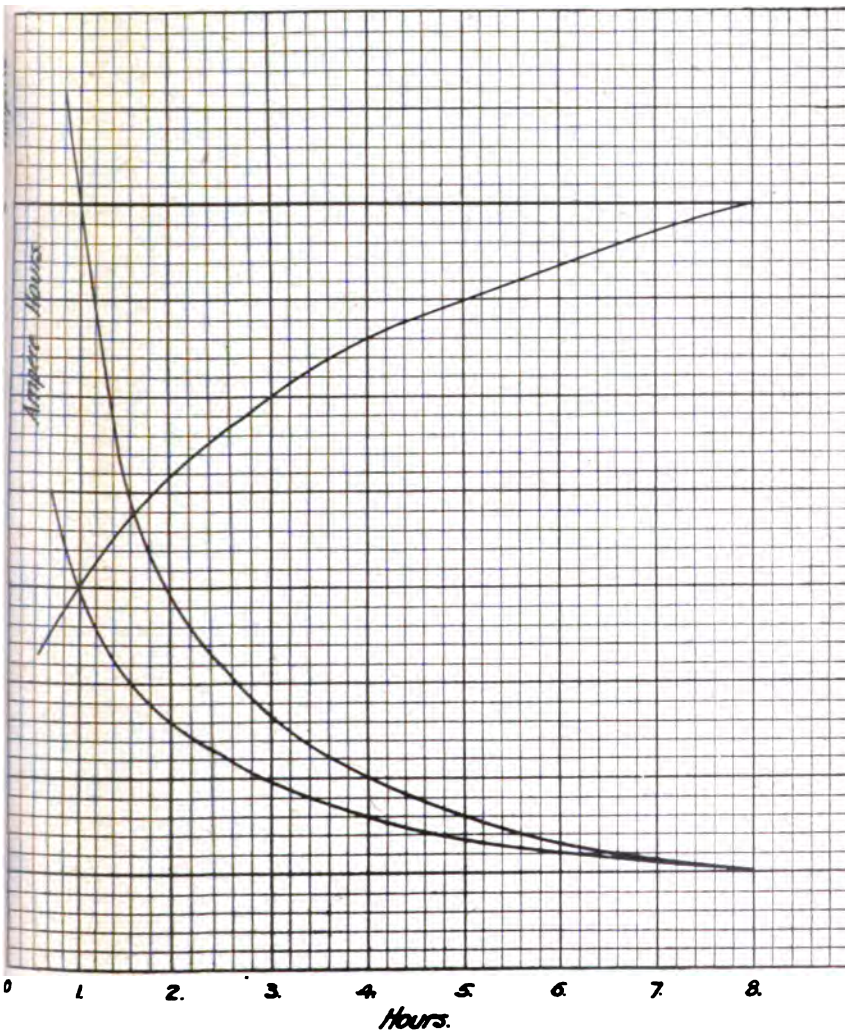


Fig. 2.

stant capacity at all rates of discharge) by taking the value of the current on X′ corresponding to that on Y′ and obtain from (1) and

$$(3) \quad i' = X \frac{i-b}{K+a\,(i-b)}$$

We have actual ampere hours $= \int_0^T i\,dt$

Equivalent ampere hours (at eight-hour rate) $= X = \int_0^T i'dt.$

Separating now the peak represented in Fig. 3 into the parts AEG and BCHF, we may represent the currents of these two figures by $i = k_1$, t and $i = k_2$ respectively, where k_1 and k_2 are constants whose determination is obvious. We shall have then the

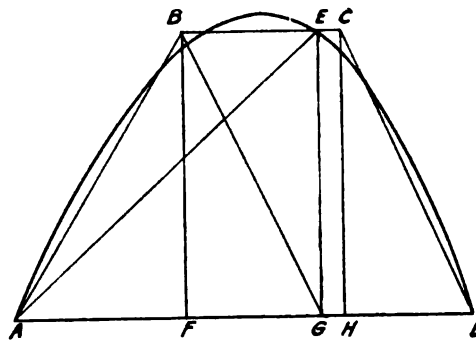


Fig. 3.

total capacity of the required battery at the eight-hour rate as

$$X = X_1 + X_2$$

where X_1 and X_2 correspond to the figures A E G and B C H F respectively. We have $X_1 = \int_0^{T_1} X_1 \frac{k_1 t - b}{K_1 + a(k_1 t - b)}\,dt$, or from this

$$(4) \quad \frac{a\,k_1\,(a - T_1)}{K_1} = \log \frac{K_1 - ab}{K_1 + a(k_1 T_1 - b)}$$

Similarly we obtain

$$X_2 = \int_0^{T_2} \frac{X_2(k_2 - b)}{K_2 + a\,(k_2 - b)}\,dt, \text{ or}$$

$$(5) \quad K_2 = (k_2 - b)\,(T_2 - a)$$

It is unnecessary to work out analytically the determination of X_2, since we can immediately determine the requisite capacity from the curves (Fig. 2.) It will, however, be interesting to check this calculation by an example.

Assume that a battery is required to furnish 1600 amperes for three hours. Inserting these values in (5) we determine $X_1 = 6400$

ampere hours, as the eight hour rating; which result is immediately checked by referring to the curves (Fig. 2).

The determination of X_1 from (4) is too complicated to attempt directly, but it may be readily accomplished as follows :—

Plot the curves :

$$y_1 = \frac{a\ k_1\ (a - T_1)}{K_1}$$

$$y_2 = \log \frac{K_1 - ab}{K_1 + a\ (k_1 T_1 - b)}$$

in the neighborhood of $X = X_1$ and the value for which these two curves intersect will be the capacity of the battery required in ampere hours at the eight- hour rate.

The question of determining the number of cells, the number of end cells, etc., may be passed over ; we have simply to divide the desired E.M.F. by the highest and lowest E.M.F.'s per cell which will occur on charge and discharge. The smaller number of cells will form the main part of the battery and the difference between the greater and smaller values will be the number of end cells.

We consider next the

DETERMINATION OF A BATTERY ON A FLUCTUATING LOAD.

Necessarily, on discharge the E.M.F. of a battery falls and on charge rises ; if, then, the battery simply floats, i.e., is directly connected into the system, either the E.M.F. of the system must decrease with increasing load, if the battery is to discharge, or if the pressure of the system is constant, the difference between the battery and line pressures must be made up in some way. In the latter case this is accomplished by means of a differential booster, which automatically adds to or substracts from the E.M.F. of the system an amount which will allow the battery to operate in a predetermined way. Usually such fluctuations are of short duration, charge succeeding discharge, and in order to determine what the battery will do, we must know its characteristics on short cycles of charge and discharge, i.e., how the E.M.F. varies on charges and discharges of various intensities and durations. This variation is a function of both time and current and graphically must be represented by a group or "family" of curves. Fig. (4) represents such characteristic curves for cells having plates of large superficial area.

Plotting the generator characteristic and preferably superposing that of the Battery (which is that of a single cell multiplied by the number of cells) we determine what the battery charge and discharge will be on peaks of different amounts and duration. Or, if the pressure is to be kept constant, we see what a booster must fur-

nish on a definite peak. It appears at once that it is of *greatest* importance that the cell characteristics (Fig. 4) should be as flat as possible, for it means not only that the battery itself will be more efficient, but also that if the battery is to "float" the pressure variations on the system will be less; if a booster is used the energy which must be supplied by the booster is less, and as, at best, the average efficiency of a booster on varying loads is poor, a flat battery characteristic is of great importance. These curves show quite a variation for different types of cells; they are flatter, in general, especially on high discharge rates, for plates of large superficial area.

Usually currents are of less intensity on charge than on discharge when a battery is equalizing a load, and this fact and its influence on the pressure variations should be taken into consideration. For a battery without a booster we would determine the number of cells by dividing the average E.M.F. by 2.07 to 2.10, if the above curves apply (according to the amount of excess charge it is necessary to allow for) and then from a load curve either actual or estimated, determine the maximum and minimum E.M.F. necessary to have the battery operate to within a definite rate.

In the case where the pressure of the system is constant and a booster is to be used, we determine from the battery characteritics, (Fig. 4) and an estimated load curve, what E.M.F. will be required to discharge the battery at the rate necessary to cover the peaks. These machines are usually motor driven and it is, therefore, necessary to add to the load curve the currents which will be demanded to operate the motor. Booster generators for batteries to cover fluctuating loads must be automatic; they are controlled by automatically regulating the booster field or its resultant by various methods. If the booster E.M.F. varies in accordance with the generator load it is sufficient to see that this latter does not vary beyond a prescribed amount when the external load is a maximum: the regulation will then be closer on lesser variations. Provision must also be made to occasionally overcharge the battery.

An extremely interesting application of storage batteries in electric railway work is their installation at points distant from a generating station for the purpose of maintaining the line pressure. They are usually termed "line" or "floating" batteries, and are an almost perfect analogy to a stand pipe on a long pipe line, furnishing a variable demand. Line batteries may be simply tied across the feeder and rail or may be fed over separate "boosted" feeders. In the latter case, if the section operated on the battery is insulated by a breaker from that operated directly on the feeders from the station, the calculation of the installation is very simple. The number of cells will be the average pressure it is

desired to maintain, divided by the average pressure per cell; this latter value is approximately 2.08 volts, but varies somewhat, depending on the state of charge at which the battery shall "float." We must then furnish the average current demanded on the battery section over the separate feeders, and the amount of boost will be this current multiplied by the resistance of the circuit, taking into account the difference between the E.M.F.'s of the power house and battery and also the rail drop due to cars on the other section

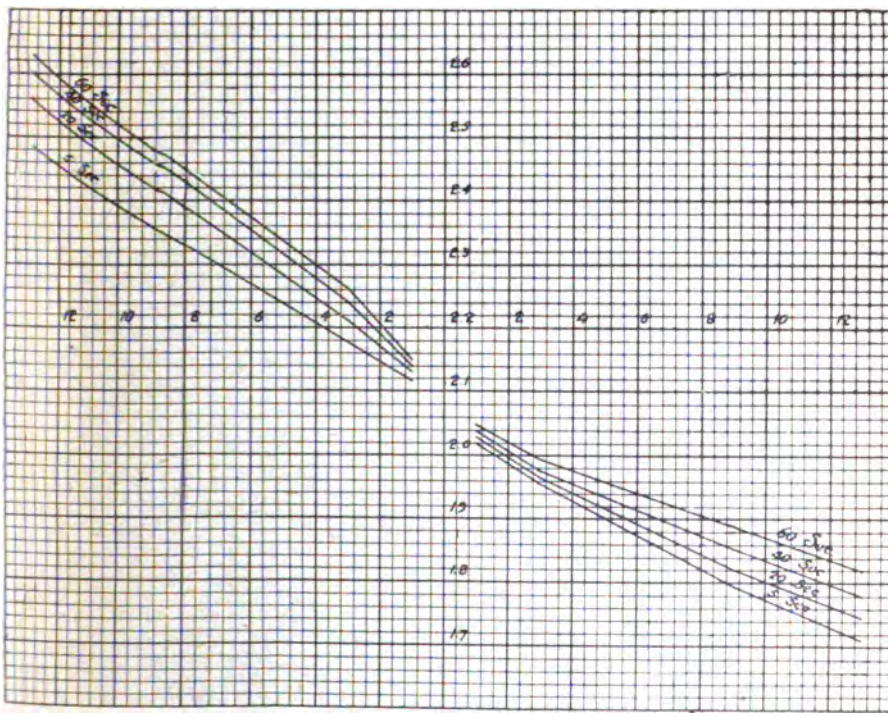


Fig. 4.

of the line. The size of the battery is determined by the difference between the maximum and average demands.

If a battery is simply floated across the feeders and rail, the calculation is not quite so obvious and we shall consider this case somewhat more in detail. We assume that there are a number of cars on the line and designate the distances of these cars, in ohms, from the power house and from the proposed battery location (which we shall call respectively stations I and II) by r_1, r_2, r_3 ---r_n; s_1, s_2, s_3, ---s_n respectively; where $r + s = R$, the re-

sistance between stations I and II; let V_1 and V_2 be the potential of the stations I and II, I_1 and I_2 the loads on these stations in amperes and i_1, i_2, i_3 —— i_n, be the currents of the various cars, then it may be easily shown that

$$I_1 = \frac{\Sigma si + (V_1 - V_2)}{R}$$

$$(7) \qquad I_2 = \frac{\Sigma ri - (V_1 - V_2)}{R}$$

It is possible to interpret these equations very simply in a geometrical diagram.

In the figure CG represents I, the total current; GH is the resistance R; $AC = MN = KJ = (V_1 - V_2)/R$ = current which would flow from Station I. to Station II. with no load on the line. The point J thus corresponds to the center of gravity of the loads. We have then $LN = I_1$ and $KL = I_2$.

We may draw this diagram for either instantaneous or average running currents. In the latter case, the line LK denotes the average *net* discharge of the battery.

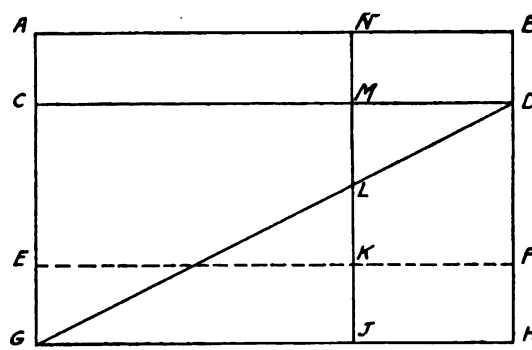


Fig. 5.

Floating batteries are quite often installed, so that over a complete cycle of the car schedule they experience neither a net charge nor discharge, excepting a certain amount necessary to make up the internal loss of the battery. In order for a battery to operate in this way all of the conditions of operation, including schedule, station pressure, feeder, etc., are fixed, and if any of these conditions are departed from, the battery will either charge or discharge. It is obviously possible with a regular daily schedule, which may, however, vary from time to time during the day, so to install a battery that the net charge during the lighter hours will equal or

slightly exceed the net discharge. This may be done by keeping the power house at approximately a constant average pressure with a varying schedule, provided the battery has the proper number of cells: if, however, the net discharge over any maximum period exceeds the ampere-hour capacity of the battery, it will be necessary either to vary the pressure at the power-house or vary the number of cells of the battery with varying schedule conditions.

In this connection it is proper to note that the capacity of the battery should be reckoned approximately at the rate corresponding to the duration of all the net discharges, and not at the rates at which the separate discharges occur. This is due to the recovery element of a battery; that is, if a battery is discharged at a high rate for a short time and then allowed to recover, and the same cycle is repeated a number of times, then the ampere-hour capacity of the battery on this work very nearly approximates the capacity at the rate corresponding to the total time elapsing.

Quite usually the conditions of operation are that in early morning and late at night the schedule is less frequent than during the major part of the day; during this latter time the loads vary at different times. Generally the calculation of a battery for this sort of schedule would be based on the determination of an average running current per car under different conditions. These values would be most suitably determined from station wattmeter readings, dividing by the pressure of the station, time elapsing between readings, and the number of cars. The battery should then be so calculated that it receives a net charge during the early morning and late at night, floating during the greater part of the day and discharging during the maximum hours. The net charge should slightly exceed the net discharge to make up for the inefficiency of the battery.

With reference to the formulas (6) and (7) and their geometrical interpretation in the diagram (Fig. 5), it is obvious that if we base our calculations on the number of cars distributed on the line, each taking the average current per car, then a battery installed at the point II, of average voltage V_2, so determined that $(V_1-V_2)/R=JK$ (that is, so that K coincides with L), will neither experience a net average charge nor discharge over an interval corresponding to a complete cycle in car schedule. If during any instant the current demand of the cars departs from the average values then the battery will charge or discharge according to the variation of these currents. It will be noticed that the center of gravity oscillates in general between certain limits even if we assume that the cars all take a constant average current. In any particular case it will appear, whether it suffices to take the point J as the average of the centers of gravity, or, if it will be necessary to take several differ-

ent positions, according to the number of cars on the sections I. to II. In case the number of cars varies from time to time it is convenient to calculate separately the components of the battery discharge and obtain the mean. In the calculations all cars beyond the battery are to be considered as concentrated at Station II.

The problem of determining a floating battery may take either one of these forms :

(a) What is the average pressure which will exist at the battery if it is to experience neither a net charge or discharge and the car schedule, station potential and line are definite ? This condition is expressed in the diagram by KL = O, that is, $(V_1 - V_2) = \Sigma ri$.

(b) How much copper is necessary to give a definite average pressure at the battery with a definite car schedule, the battery to be maintained at a constant average state of charge ? The diagram gives for this condition KL = O, that is JK = JL $= (V_1 - V_2) / R$ and, therefore, R is determined.

(c) With definite car schedule, E.M.F.'s and line, what will be the net charge or discharge of a battery ? This we obtain from the diagram and have KL = JL — JK, the discharge.

It has been objected, that in the application of this method, no account has been taken of the variation of the E.M.F. of the battery on charge and discharge. If the battery is to "float" it is obviously unnecessary to do so as these variations are approximately linear functions of the amount and duration of the charge and discharge, and since these amounts are equal no appreciable error is made in assuming the battery E.M.F. as its average. In any event the method gives a close approximation and results obtained through its application are correct to within one or two per cent. To attempt to introduce this pressure variation in the calculations would involve an enormous amount of work and would be practically *impossible* since both the magnitude and duration of the current discharges from the battery would have to be taken into account.

Batteries are sometimes installed where in addition to floating on the line, they receive a charge component over a boosted feeder. The consideration of this case would be simply an extension of the above method.

We shall not, however, carry it out as the scope of the present paper is more to indicate methods of calculation in different cases than to treat any one application exhaustively, which object the writer trusts has been accomplished.

MINING SECTION.

President—G. H. DUGGAN.
Vice-President—J. B. PORTER.

At the meeting of the Section, held on Thursday, Feb. 25, Dr. J. B. Porter in the chair, papers were read as follows:—

PAPER No. 204

METHODS OF MINING AND TIMBERING IN LARGE ORE BODIES IN BRITISH COLUMBIA AND MICHIGAN.

By NORMAN W. PARLEE, S. Can. Soc. C. E.

The method of mining to be adopted in any particular mine depends upon a number of important considerations. Among these may be mentioned the size and attitude of the ore body or deposit, the hardness and rigidity of the ore and adjacent rock, the quantity and quality of timber available and its cost, the price of labour, and the value of the product to be mined. Generally speaking, if a narrow vein is to be worked, stull timbers are used, the limit being a width of about 15′. As the vein widens beyond this, stulls are out of the question, and another system must be adopted. The method then employed may be the square sett system, or a filling method, except in case of soft ore, when a caving system may be followed. There are a great many modifications of all these systems to suit circumstances and conditions, and it is the intention in this paper to describe and discuss them as carried out in those mines in which the writer has worked, and in which he has become more or less familiar with the methods in successful operation.

The names of the mines treated, and location, are as follows:—

Le Roi Mine.....Rossland, B.C.
Old Ironsides.....Phoenix, B.C.
Baltic Mine.....Baltic, Mich.
Atlantic Mine.....Atlantic, Mich.
Barnum Mine.....Ishpeming, Mich.
Section 16.....Ishpeming, Mich.
Soft Ore Hematite.....Ishpeming, Mich.
Queen Mine.....Negaunee, Mich.

In nearly all these mines the methods used apply principally to mass mining in large bodies of ore. The one exception is the At-

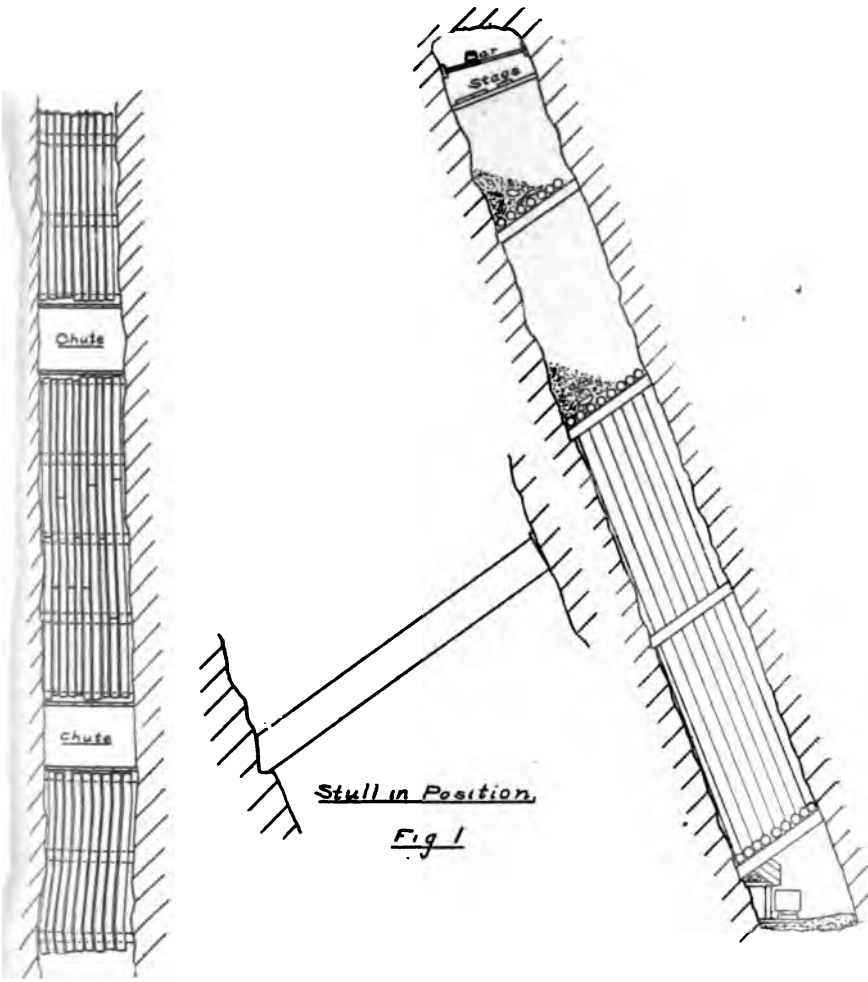
lantic Mine, which has a narrow deposit, and is mined entirely by the old fashioned stull method.

LE ROI MINE, ROSSLAND, B.C.

In this mine there are one or more veins or ore chutes of varying width and carrying the minerals pyrrhotite, chalcopyrite, and iron pyrites, and mixed with these more or less disseminated gold. It is the gold, however, that affords the principal value of the ore, and without it there would be no Rossland. The vein is of a pockety nature and some of the pockets are of very large size. The dip is about 70°, and an incline shaft was sunk at about this slope. As depth was attained it was found that the vein pitched a little steeper, and the shaft was given a steeper pitch also, thus forming what is called a "knuckle" in the shaft. This knuckle afterwards became a source of considerable trouble, because, at high speeds, the skip was liable to leave the track.

At intervals of 100′ drifts were run on the lead, and the deposits thus opened up. The first shaft had three compartments timbered with the ordinary square shaft setts. Sinking was carried on with three shifts of miners working eight hours each, and the rock broken was hoisted to the level above with a bucket and air hoist. As the shaft became deeper the ore and rock were hoisted by skips, run on the balanced principle. A pentice of about 15′ of rock was always left in the shaft at each level, and served as a protection to the shaft men working below. It was located under the two hoisting compartments, and connection was made below by a passage at the side. Each drift was usually excavated before being timbered.

At each level, drifts were run on the vein in the ordinary manner, dimensions being 6′ x 9′. In the earlier workings the tracks were laid very poorly, and were often the cause of a great deal of trouble and delay, when a large output was desired. But as time passed improvements in this, and many other respects, were inaugurated, and the tracks were laid to a grade of from 7″ to 10″ per 100′. Track-laying is a very important matter in the economy of a mine, and a good track will always pay for itself many times over. The tracks should not only be good, but there should be plenty of them, and placed so that they will be close to the rock to be removed. In drifts moveable lengths of 8′ or 10′ should be used. This saves shovelling to a long distance by placing them in position as soon as there is room, and enables the mucker to work to advantage, until there is sufficient space for the ordinary 16′ or 20′ rails. The rails are laid on 4″ x 6″ ties, 3′ in length, and placed about 4′ apart, the rails weighing 16 and 20 lbs. to the yard. The waste rock encountered in development was trammed to the shaft and sent to the surface, though now most of it is filled into the stopes of the upper levels.



Stull Timbering – Le Roi Mine.

When the miners began to stope on any level, an upright post was rigged, and the holes pointed upward and backward. On a narrow part of the vein a cross-bar was often employed, which enabled the muckers to tram beneath from another part of the level, while drilling operations were being prosecuted. Whenever convenient, however, the miners prefer to rig upright, as they can drill more advantageously from that position. As they climbed higher on the vein, hitches were cut in the foot-wall, and stulls were put in from foot to hanging walls. One end was fitted into the hitch, and the other end cut with such a bevel that it fitted against the hanging wall, which had been previously faced if necessary. (See Fig. 1.) The greater weight coming on the stull, the more securely it would remain in place. These stulls were placed tightly in position, and wedged if necessary or possible. If there was any liability of their being knocked out by blasting, a hitch was also cut in the hanging wall. Stulls were used to form floors to work from at intervals of nearly 20′, and such a distance apart horizontally that the lagging placed upon them would not be broken by the blasts above. They were also put up against any bad ground that required them. The lagging used on the stulls consisted of round poles, and plank chutes were run up the stope at convenient intervals.

An idea of the stope and chutes may be gathered from Figs. 2 and 3. A cross-bar and stage is shown in Fig. 2, but usually most of the work is done from the broken ore resting on the stulls, and an upright post is rigged, either on this ore or on benches on the footwall.

But where the ore body widened stulls could not be used. Here the stope was started by enlarging the drift to the total width of the deposit, and a face obtained right across the vein. In one case the width varied from 40′ to 80′, and, as a back or roof of this size would be dangerous to work under without some support, the timber had to be quite close to the face. When the muck was removed mudsills were laid down, upon which the sill posts were erected. These sills were carefully placed, and tamped with fine dirt. They were braced apart by cross ties, and had a length of 16′ or three setts. The framing and manner of laying them is shown in Fig. 4. At first the sill floors were not planked over, but later it was seen that a plank floor was economical to shovel from, as often there would be rock tumbling down, or breaking through from the floors above.

On one level in the Le Roi, the 700′ level, there were no fewer than 8 machines working at the same breast simultaneously. This meant that the rate of advance was very rapid, and difficulty was experienced in keeping the timber close enough to the face. Two parallel tracks were laid to remove the ore, one along the footwall side and one along the hanging wall side, and a large gang of muckers and

timber men became necessary. When the sills had been laid down square setts were erected upon them, and securely braced or spragged. Spragging a set of timber requires considerable experience on the part of the timberman. Spraggs are pieces of round lagging, cut square at each end and of varying length, and placed between the ground and the caps or ties, as the case may be, and securely wedged. They serve to keep the setts rigidly in their proper position, and thus prevent them from falling down during concussion after blasting.

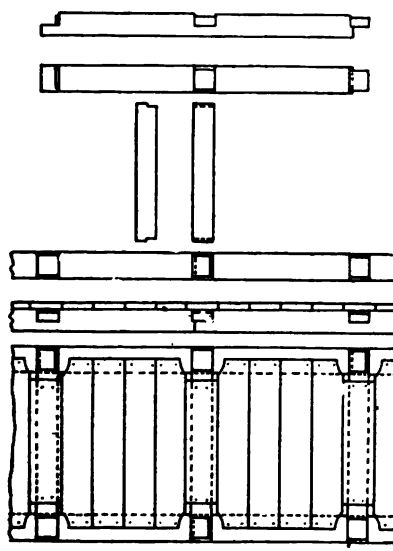


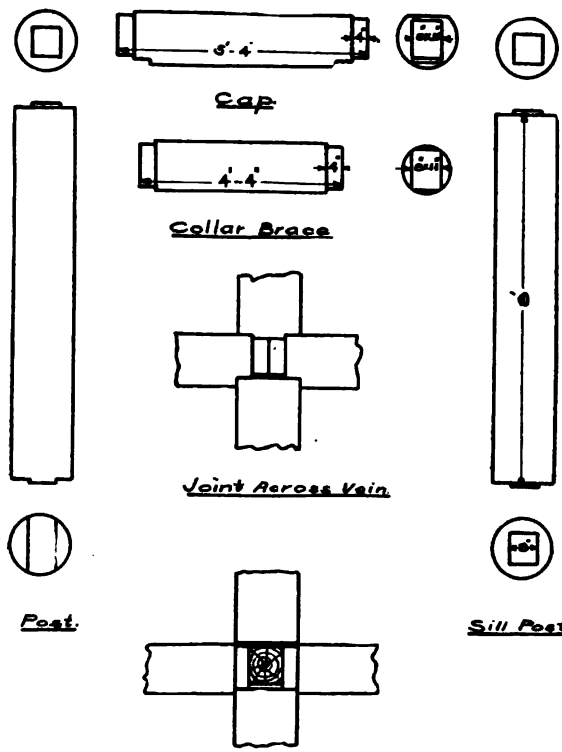
Fig. 4.

Mud Sills and Ties.—Le Roi Mine.

The details of the square setts are shown in Fig. 5. These were at one time framed by hand, but now a framing machine does the work. The setts are shown in position in Fig. 6. This is a view of a section across a rather narrow part of the vein. One post on the foot wall is placed in a special manner to avoid the necessity of cutting a large hitch in the rock, which is very hard. A hitch is often made when it can be cut without too much trouble. On the hanging side an extension cap is shown, no hitch or support being made for the end of it. The top "butt" cap on the hanging side is

supported at the end by a heavy pole instead of a post. The plank floor, lagging and spraggs are shown at the top.

The posts, used in the Le Roi ranged from 12″ to 24″ in diam., the caps 12″ to 15″, and the collar braces or ties somewhat smaller. In the old days it was the custom to cover the caps with round lagging, 16′ long and up to 7″ in diameter. They thus reached over three setts,



Joint Along Vein.

Fig. 5.

Details of Square Setts—Le Roi.

but were difficult and awkward to handle, on account of their length. After several years of this inconvenience it was decided to cut them so they would reach only two setts. The lagging was then brought to the mine in lengths of 20′, and they were sawed in half on the surface. A double tier of lagging was used, one tier

being laid on the caps and the other at right angles to them. Still later in the history of the mine 3″ planks in 5′ lengths were laid on the caps, and a few rough holes placed on top of them, to prevent the plank being broken by the blasts. These planks were spiked with one spike in each end, and served to stiffen the timber considerably.

When the excavation on the level had advanced a reasonable distance, say about 60′, another floor was started on top of the timber. Overhand stoping now commenced and rock or ore was broken much more readily than on the sill floor, as it had a better chance to break,

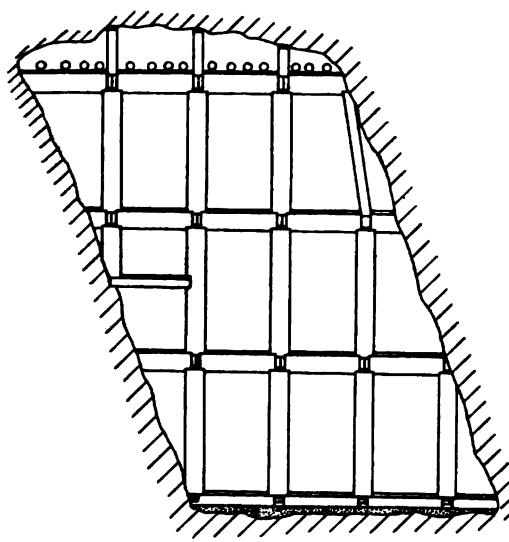


Fig. 6.

Square Setts in Position.

there being more free surfaces. Holes were drilled in a face about 7′ or 8′ in height, and placed so as to bring the ore down to the best advantage, viz., enough holes were drilled and enough powder used to break the ore to convenient size for economical handling. If it were broken too fine it would take too long to shovel-into chutes, while if it came down in the form of large bowlders it was necessary to blast. The sizes most conveniently handled were lumps weighing from 25 to 50 lbs., which could be rapidly and easily thrown or pulled into chutes. The holes were generally drilled in the direction of the vein or ore body, and not across it, the depth being about 7′. At each set-up the miners moved across the face from foot

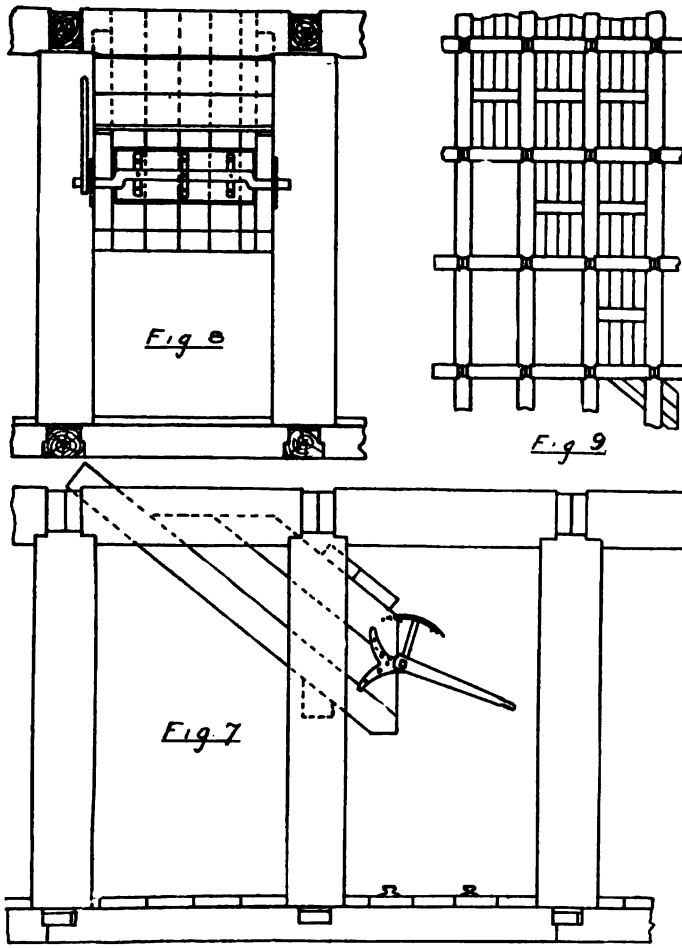
to hanging, or vice versa, as the case might be. In this way the muckers cleaned out the broken ore behind, and, as soon as there was room, the timbermen proceeded to put up the timber.

To get out the ore, chutes were built in every other sett, or every third sett at most. The bed pieces were made of 8″ x 10″ timbers, placed at proper slope for the rock to roll down, one end being on the collar brace, and the other supported by a cross-piece inserted between the posts, and high enough to enable the one ton ore cars to pass beneath. Figs. 7 and 8 show a side and front view of a chute respectively. The chute door or gate consisted of a semi-circular sheet iron plate, with suitable stiffening to prevent deformation, and a lever attached by which to operate it. By means of these chutes properly made, and with dry ore, the car could be filled in a very few seconds.

As more floors were constructed above, the chutes were carried up the full size of a sett, by spiking plank 8′ 8″ in length on the caps and collar braces. To bring them closer to the ore, as in a large stope, the chutes were expanded to take in two, three, and even four or five setts. (See Fig. 9.) The chute planks were all placed vertically, and where it became necessary a bottom of short lagging was made for the rock coming from above to fall upon. A stiffening was made for the chute planks by cross brace between the posts, half way up and well spiked. In a wide stope, two rows of chutes and two lines of track were constructed. By this means the muckers were enabled to get the ore into the chutes without being compelled to throw it far, or to use wheel barrows or any other device.

While any level was being developed a winze was sunk from the level above to provide ventilation. These winzes were always located in the stopes, and provided a sort of chimney by which the smoke had a chance to escape. They were also used as an easy route by which timber could be lowered to the upper floors, and later, when the ore had been all removed, or nearly so, waste rock was run in through them to fill up the stope.

As more and more floors were attacked and carried forward, more faces were worked simultaneously. Care had to be exercised in regard to approaching too near the front line of timber. The blasts might jar the timber, and possibly cause it to throw forward a few inches, even if they would not knock it down. When square setts have been disarranged in this manner, it is a very difficult matter to force them back into position again. The writer has had occasion, as a timberman, to use jack-screws in cases of this kind, and to spend considerable time on work which, with a little more caution on the part of the miners or the management, would have been unnecessary. One machine at a face and one machine at every other



Views of Chute—Le Roi Mine.

the level below. Here the timber was attached with a hook and half hitch, and hoisted to any floor desired. An idea of this arrangement may be gathered from Fig. 10, in which one timber chute is shown beside an ore chute. The timber chutes were made of 2″ planks, spiked to the collar braces, and inclined with the vein. They were erected every 80′ or less, and were convenient for hoisting drills and machines, as well as timber. The timbers could be readily dragged to any place desired by means of the "come-alongs," which were a pair of hooks attached to the centre of a small pipe 3½′ in length. A man on each end of this pipe could drag a post anywhere over the floor.

The ore was not sorted in the mine, but sent to the surface to be treated there. It was trammed to the shaft and dumped into large pockets from which the skips were loaded. The tracks at the shaft were laid directly over the pockets, and the ore was dumped from the car between the rails, or at one side of them. These pockets were capable of holding a good many tons so that, if anything happened to the hoisting apparatus, the trammers could still work away, and fill the pockets. In the new shaft, which was put through by means of raises from each level, pockets were made with a capacity of about 200 tons.

From this somewhat detailed description it will be seen that a great deal of timber is used in this mine. The timber is not used merely to hold up the hanging wall and roof, but principally to furnish a convenient method of reaching all the ore, and to prevent loose slabs and bowlders from dropping on those who must work beneath. The workings are kept closely timbered, and thus liability to accident is reduced. No staging is needed in rigging machines, the muckers have a good floor to shovel from, and chutes are handy and convenient, more so than could possibly be the case in any other mining method.

By this system all the ore is taken out between levels. The sills of one level are caught up from beneath, and timber connections made with the level below.

When a stope or level is worked out the only timber saved is the rough lagging and plank flooring, which is readily torn up and used again. Waste rock from development work in other parts of the mine is dumped down, and the old stope gradually filled up. This rock is brought up from the lower levels on cages in the new five-compartment shaft. No great attempt is made, however, to fill the stopes.

Old Ironsides Mine, Phoenix, B.C.

In this mine and the adjacent Knob Hill, we have a still wider and larger ore body than at any point in the Le Roi. Not only is the

deposit of immense size, but the grade of the ore is much lower, necessitating a much lower cost of extraction, in order to mine it at a profit. To accomplish this a large output is essential, and cheap and rapid means of handling it, from breaking the ore down until it finally reaches the smelter.

The ore is mined in three ways in these deposits:—

(1) By open cuts,
(2) By the milling or "glory hole" method, and
(3) By the ordinary overhand stoping with the use of square setts.

The open cut was on a level with the railroad track, and a tramway was built with an incline to enable a small hoist to bring the ore up high enough to dump into the railroad cars. This is quite an ordinary method and needs no further comment, the ore being broken down in the usual way. Later, however, when a considerable excavation had been made, a steam shovel was used, which handled rock of much larger dimensions. Bowlders too large to go into the bucket were picked up by means of a chain. They were loaded either directly into the shipping cars, when the ore was crushed at the smelter, or into small wooden cars, and taken to the crusher first by horses, and at the present time by a small locomotive. Three steam shovels are now at work for this company in their low grade ore bodies, and they will tend greatly towards solving the problem of decreasing the cost, and, at the same time, largely increasing the shipments.

The milling or "glory hole" method also applies more particularly to the Knob Hill than to the Old Ironsides Mine. It consists essentially in driving a tunnel into the deposit to be excavated, as low as can be conveniently worked without the sides caving in, and then a raise to connect with the surface. At the bottom of the raise a very substantial chute is constructed from which the ore can be readily withdrawn into cars. Operations then begin on the surface and the ore is milled or broken down, being blasted into the raise. Suitable faces and benches are soon established, and a better command obtained of the size of the rock going down the chute or raise. Very deep holes are drilled and very heavy blasts set off, thus breaking the ore quite rapidly and economically. The benches are arranged in such a manner that a great amount of the rock rolls down into the chute, which is always partially filled, without much handling.

The advantages of this method are as follows:—

Practically no expense for timber.
No bad air to work in and hence no time lost.
Few drill holes needed and comparatively little powder used.
The ore handled mostly by gravity.

The disadvantage is that there is a limit to the depth at which the ore can be excavated, because of the caving or falling in of the sides.

On the deeper levels of the mine the usual method of underground development was carried out. The system of mining the

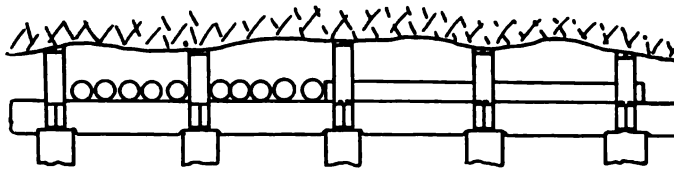


Fig. 12

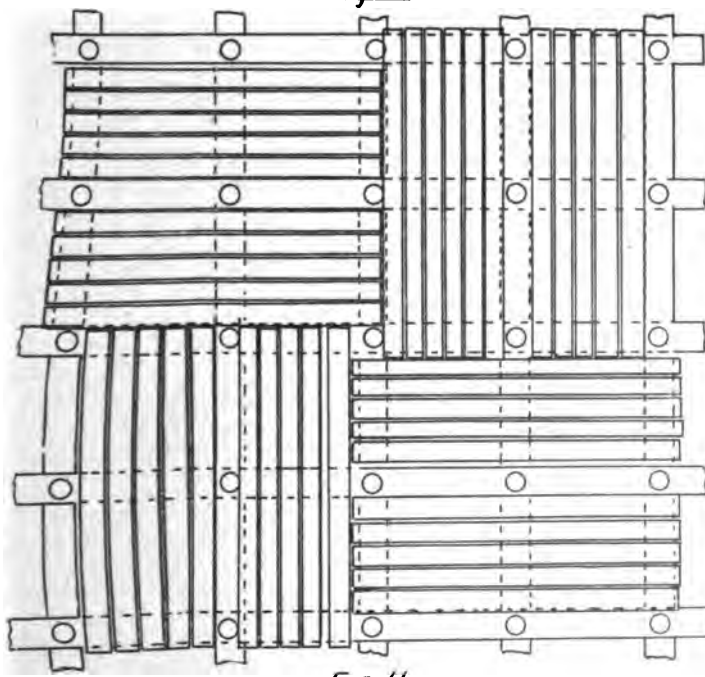
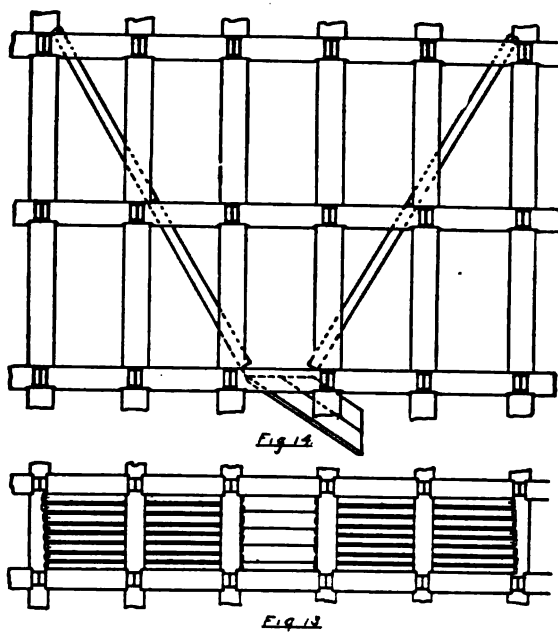


Fig. 11

Lagging Arrangement—Old Ironsides, Phoenix, B.C.

ore was very similar to that in vogue in the Le Roi, which has been already described. The timbers, however, were stouter, and the method of lagging was different. In arranging the lagging the object was to place it in such a way that the broken ore could be rolled

into the chutes with the least possible amount of shovelling. To accomplish this, lagging about 10′ long was laid on the caps, close together, and, if the poles were weak, perhaps a double layer. A space two setts square had the poles laid parallel, and the adjacent squares were poled at right angles to these. The caps and collar braces were of the same dimensions, hence it did not matter which way the lagging was arranged. In this way the poles had a good support at both ends, because they reached well over two 5′ setts.



Chute Arrangement—Old Ironsides, Phoenix, B.C.

When it was desired to remove the muck, all that was necessary was to move a pole so that the ore could drop through. As it rolled down, with the aid of a pick or bar, another and another pole could be rolled from beneath it. In this manner the writer has rolled into the chute 40 or 50 tons in four or five hours. Any very large bowlders, of course, were smashed with a sledge hammer. Fig. 11 is meant to show the arrangement of the lagging. It is a plan of the floor immediately under the ore to be mined, while Fig. 12 is an elevation of the same.

A special method of chute building was adopted here. Above the first floor they were built in the shape of a long trough-like V

running from one brace down and across to the next. Poles were used for this work, and spiked securely to the square setts. Figs. 13 and 14 show the arrangement of the chutes in plan and elevation. At convenient intervals an outlet was made, and between each chute gate the ore was allowed to pile up a little. The ore was trammed to the shaft in ordinary one-ton cars, and hoisted to the surface on a cage through a vertical shaft.

It will thus be seen from this brief account that a very easy and economical method of removing the ore was in vogue at the Old Ironsides.

Baltic Mine, Baltic, Mich.

The method adopted in the Baltic is peculiar to this mine, and is not used, as far as the writer is aware, at any other mine in the Copper Country. It is a simple system of walling up each tramway with waste rock, thereby keeping a roadway open, and filling in above with the gangue and country rock, as convenient. In this way the expense of putting in timber is minimized, which is offset by the walling and filling. The method is only applicable when the vein carries waste, or when waste rock is easily and cheaply obtainable.

The material mined is native copper which occurs in a vein of lava rock both as "shot copper" of varying size scattered throughout the rock, and as "mass copper," which is solid copper of more or less irregular shape. The pitch of the vein is about 70° or 72°, and the width varies from 20′ to 50′. Parts of the vein are more or less barren of copper, and this rock, called "poor rock," is picked out by the "copper pickers," and forms a good part of the filling.

The vein was opened up by shafts and drifts, and when stoping began, the drifts were widened out to the full width of the vein. After the copper rock was cleaned out from the face, the poor rock was taken back in cars, and shovelled to one side. When the "wallers" had enough rock to start on they began and walled it up on each side of the track, leaving a space of 7′ for a tramway. The walls were made about 7′ high, and heavy stull timbers laid on them as caps. These caps were placed about 3′ apart and covered with cedar lagging, so that no rock could come through. (See Fig. 15.)

At intervals of about 40′ spaces were left for chutes on one side of the track. They were built up with rock and had a timber margin for planks to be spiked to. In the bottom of the chute flatted hemlock timbers were laid, and a heavy sheet iron plate was fastened to them with drive bolts. The bottom of the chute was made flat because very large bowlders were handled in it. For a gate a spout was used, one end of which was raised and lowered by means of a long stout lever. The copper rock thrown into the chute was pulled

out by the trammers into two ton cars, taken to the shaft, and dumped directly into the skips.

When the work had progressed far enough on the station level, overhead stoping began above the caps and walls, by drilling with

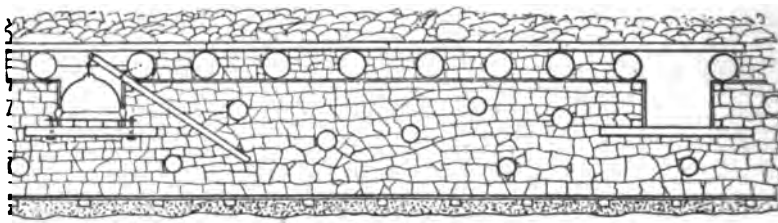


Fig. 15.

Section along Tramway, Showing Wall, Mills, etc.

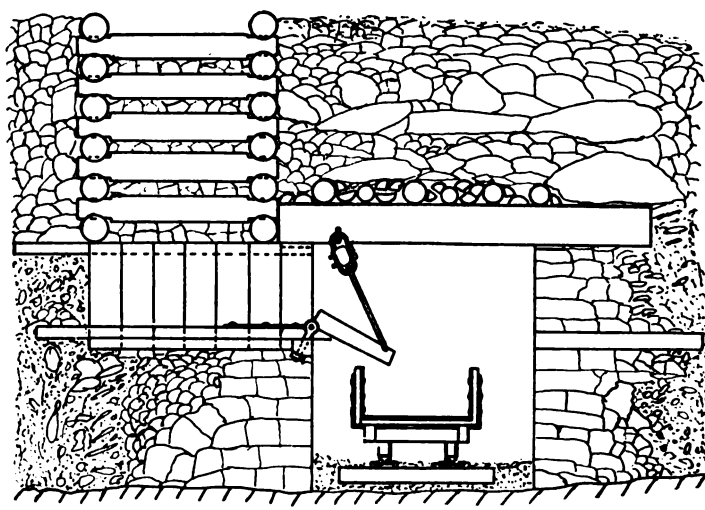


Fig. 16.

Cross Section at a Mill—Baltic Mine.

machines and blasting in the usual manner. The rock broken down was picked over by the copper pickers, the copper rock being thrown into the chutes, and the poor rock thrown back to fill up the excavation. As more and more filling accumulated,the chutes were carried upward in the form of a hole 5′ square. by means of heavy cribbing flatted at the ends and spiked. (See Fig. 16.) Sometimes the

pickers needed wheelbarrows to get the rock into the chute or "mill."

In stoping, a good breast was carried along, and heavy holes drilled, since no damage could be done by heavy blasts, though it was not advisable to shatter the roof too much. As the room grew in height the back got farther and farther away from the filling. This necessitated the use of long posts for the machines and staging for the miners to work from. The idea, of course, was to work as much as possible from the top of the broken rock, but as there was 100′ between levels, and not a very high percentage of poor rock, it became necessary to cut out the foot or hanging walls to fill in, and

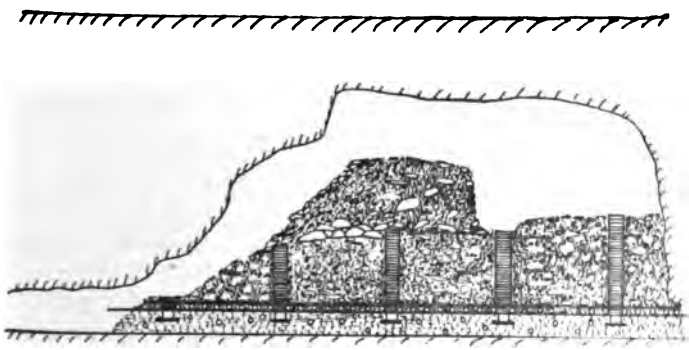


Fig. 17.

Longitudinal Section of Stope—Baltic Mine, Mich.

thus reach the back. This should always be done after the copper rock has been picked out, as otherwise much poor rock would be mixed with it. An attempt is made to convey an idea of the stope in Fig. 17.

This method is supposed to take out practically all the ore, and the only use made of timber is to crib the chutes, and cover the tracks. The vein rock is quite tough, and, with a slight arch in the middle of the roof, there is comparatively little danger from overhead. The greatest difficulty to be encountered will be in making connections between levels. Here the filling from the level above will run down and mix with the copper rock below. Taken altogether, however, this is an excellent method of mining, and has given the Baltic people satisfaction up to the present time.

Atlantic Mine, Atlantic, Mich.

The Atlantic vein is similar to the Baltic, though it only averages

about 15′ in width, and it does not carry so much copper. This rock is not picked over, but the total product mined goes to the stamp mill. Thus no filling can be obtained from the rock broken and, the vein being narrow, stulls can be used.

When the levels have been opened up the miners take contracts to stope out the pay rock. Each contract includes a part of the vein 99′ in length and extending between levels, which are about 85′ or 90′ apart, and the price is paid on a basis of at least a width of 15′. The contractors first run a drift to the end of their ground and commence stoping, taking out enough rock to put in the stulls to protect the level for tramming.

These stulls are very heavy, about 20′ or more long, and placed in hitches cut in the walls. They are inclined at an angle of about 70° to the horizontal, thereby leaving room for a track be-

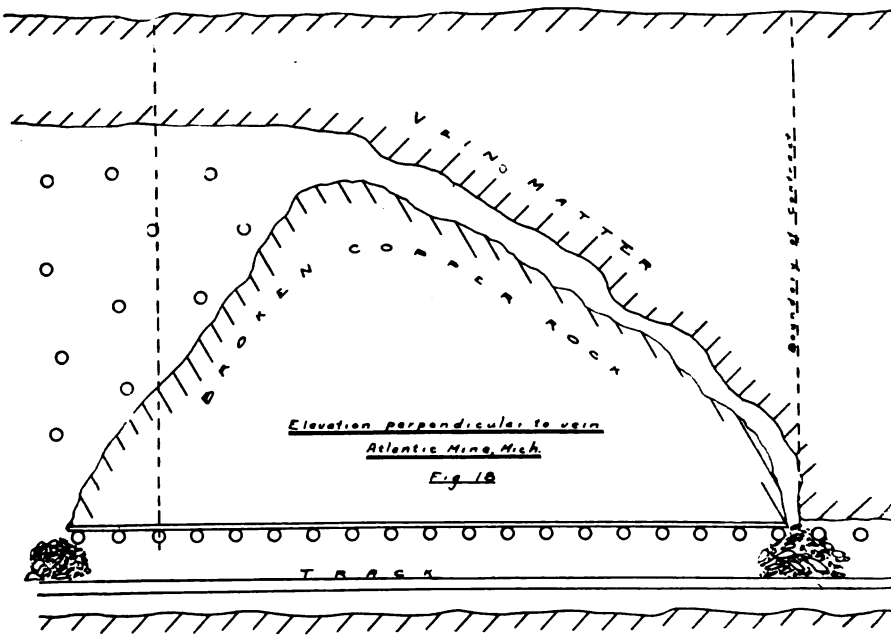


Fig. 18.

tween the stulls and the hanging walls. (See Fig. 18.) At the same time they were quite steep to prevent them taking up more weight than they could safely bear. They are covered with lagging, which prevents the muck from coming down on the track. When this line of stulls is finished, stoping is commenced higher on the vein. The miners keep rigging up on the rock they break, and it is

trammed out from below when they are crowded for head room. In this way they are always close to the back, and work to the best advantage. They work up to within 15′ of the level above, and then, as the rock is withdrawn, the timbermen place stulls wherever they are needed to support the hanging, and make it safe for the muckers below. The pillars left constitute the floor of each level.

This method furnishes one of the cheapest and best methods of getting out stamp rock in the copper country. The width of the vein, its regularity and pitch or dip, make this a peculiarly valuable method to the Atlantic Co. Without it the mine would probably be operated at a loss, as the copper values do not exceed 25 lbs. per ton of rock.

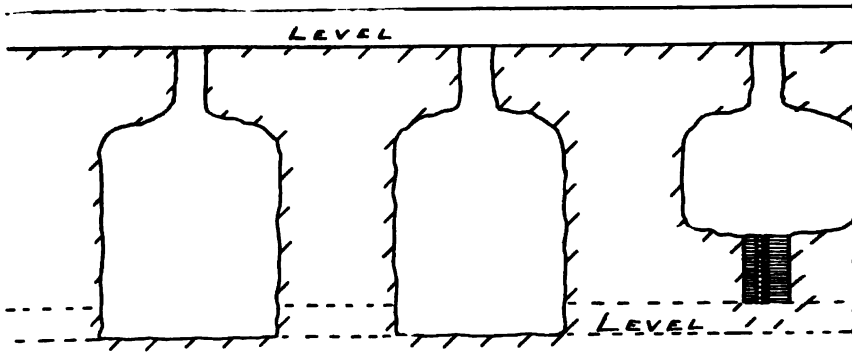
Coming now to the Iron Country of Michigan we find a somewhat different order of things. Here we do not have the ores in regular well defined veins, as is the case in the copper country. On the contrary, the ore occurs in blankets or deposits of more or less irregular shape, and the sustaining power of the adjacent rock is a far more uncertain quantity. The ore itself varies a great deal, some being soft and capable of caving, while much is hard, and a caving system could not be adopted. Some again is intermediate between hard and soft ore, and a combination of a caving system with some other method becomes a necessity.

Barnum Mine, Ishpeming, Mich.

This is a hard ore mine producing a hard hematite. The system of mining is simple and inexpensive, although about one-third of the ore is left for pillars. The levels are from 40′ to 50′ apart, and after being driven, raises are run up to the level above at convenient intervals. When the raises are completed, the miners begin at the top and mill the ore down the raise in a manner similar to the "glory-hole" method already described, except that the work is, of course, underground. They work from convenient benches and gradually cut out large chambers. Care must be exercised in scaling any loose rock from the roof while the men are close to it, because when they get lower down the roof will be out of reach. Wherever necessary, pillars are left 22′ square, one being as nearly as possible directly above the one below. Machines and tripods are employed, and the rate of drilling is slow, varying from 4′ to 15′ of hole per shift. The ore is also hard to break, and a 50% dynamite is used. There are no pockets in the mine, and the cars are hoisted to the surface by a single compartment shaft. As the method at the Barnum is so simple, little more need be said; suffice it to say that the method is very wasteful of ore, because such a large percentage of it is left in the mine.

SECTION 16 MINE, ISHPEMING, MICH.

The ore from this mine was also fairly hard and a similar method of mining was adopted. Levels were run from the shaft



Stopes and Pillars.

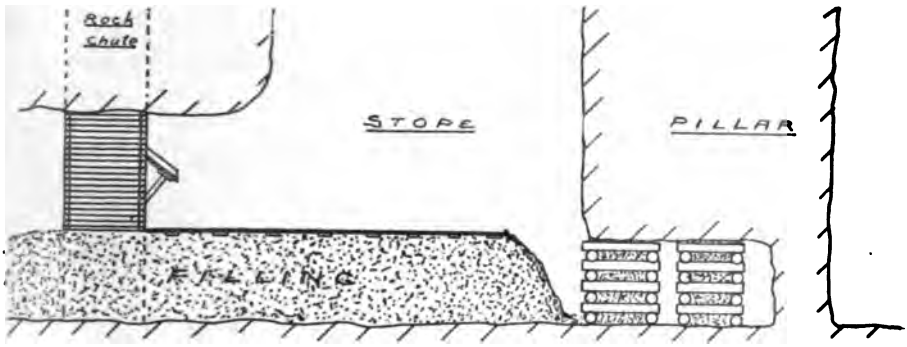
to the ore body at intervals of about 60′, and a drift run along the foot or hanging wall as desired. From this drift raises were driven every 50′ to the level above, thus making a passage for timber and ore. At 15′ below the upper level the raise was enlarged into a stope or room, and made of such a size that it would be safe to work in, dividing pillars being left on each side. The ore was thus removed down to the level below, and pillars were left extending across the ore body.

When the rooms had all been excavated in this manner the robbing of the pillars began. The pillars were usually 25′ through, and they were undercut on one side to a distance of about 9′, and right across the vein. The timbermen then built cribs of timber 8′ square in this space, and as many as they had room for, leaving a space of 3′ between each for a passage. These cribs were built right up to the back, wedged down and filled with rock.

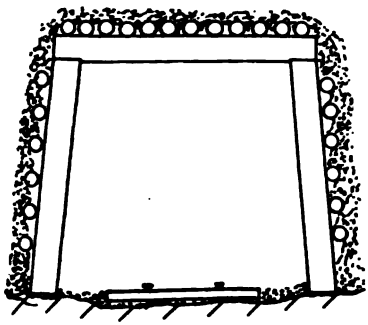
The next step was to undercut another 9′ and treat it with timber cribs and rock in a precisely similar manner. Finally the last portion of the pillar was removed and cribbed, and the pillar rested now entirely on the crib supports. The stopes on either side of the pillar are then filled with loose rock to the level of the top of the cribs, and also in between them, a passage way, of course, being left for tramming.

The pillar having been undercut to a height of about 8′ another slice is removed in much the same manner, at a higher level. Mills

become a necessity in order to let the ore down through the rock filling, and these are made of round poles and placed at convenient intervals. As the pillar was attacked at a higher point the work proceeded on the top of the filling, hence by this method it was possible to remove practically all the ore.



Robbing and Filling.



Tramway Sett

Filling System

Section 16 Mine.

Fig. 19

The filling used is obtained from two sources: part is furnished by the ordinary development work, and the remainder is obtained from the dump of a neighbouring mine. It is loaded into railroad cars, and dumped directly down a raise for that purpose. This raise is tapped where desired by a rough chute, and the rock trammed in small dump cars running on tracks laid on the filling. These tracks are readily moved laterally so that the rock is conveyed to the place desired without very much shovelling being required.

In parts of the mine where the ore body is of such nature that ore pillars are not necessary, a method of overhand stoping is prosecuted. This operation is followed directly by the filling, the ore being mined out and the excavation filled with waste rock. Where the roof is not good, cribs are built on the filling to support it.

Again, in other parts of the mine, filling is not used, but the ore is mined from each level upwards, and the regular square sett timber erected.

The methods of mining at this mine are therefore somewhat special and varied. The cause of this variation is due to the fact that the ore body changes from place to place in hardness, width, and accessibility. In some parts of the mine it is hard to introduce the filling, while in others it is a cheap and efficient adjunct in extracting the ore. Wherever used it forms a compact and satisfactory substitute for timber, which, to perform the same duty, would be quite expensive.

Soft Ore Hematite Mine, Ishpeming, Mich.

Here we have a mine which was formerly covered by Lake Angeline, a body of water of about 100 acres in extent, and 50′ deep in the deepest part. The water was pumped out by means of powerful pumps, and the lake bed became comparatively dry. On the margin of the old lake, shafts were sunk, and the mining of the large deposits of soft ore begun. The ore, being a soft red hematite, was very easy to break down, but it was impossible to have large chambers excavated, because of its heavy settling nature. As the soft ore caved so readily, a caving system of mining was soon inaugurated.

Haulage ways were, as far as possible, made in solid rock. Then raises were driven to the top of the ore deposit, at intervals of from 60 to 100 feet, and cribbed with two compartments, one for a ladder road and the other for ore. Sub-levels were also made to facilitate operations. The ore was loaded into cars holding about 2½ tons, which were attached to a "bull-dog", and taken to the shaft in trains of six or seven. The bull-dog was operated by a cable, each end of which passed around a drum run by compressed air. One engine was located at the shaft and the other at the end of the haulage way. At the shaft the cars dumped directly into the skip, and were moved up to, and away from, the shaft by hand. The idea of the bull-dog is to facilitate coupling, the cars being connected to the bull-dog instead of directly to the cable.

When the chutes were completed a "top-slicing" scheme was begun. A drift 8′ x 8′ was driven parallel with the deposit, and timbered with square setts. These setts consisted of legs and caps as

shown in Fig. 20, and placed 4′ apart. At the raise it was important to have rather stout timber, because here the timber was expected to stand the longest, and was therefore subjected to most pressure. Farther from the raise or chute the timber was much smaller, 6 to 12 inches, and the caps were covered with light lagging. The caps, as a rule, were a few inches larger in diameter than the legs.

The second step in top slicing is to begin at the farthest end of the drift and crosscut to both foot and hanging walls. These drifts

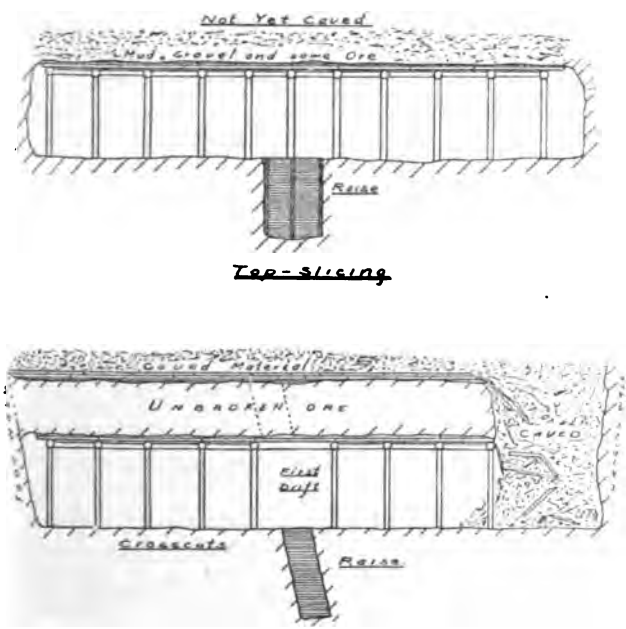


Fig. 20.

Caving System, Soft Ore.—No. 2 Hematite Mine.

are also 8′ x 8′ and are driven parallel, and one after another, until the whole area is excavated, that around the chute being taken out last. The same procedure is followed on the opposite side of the chute. The floor is then all lagged over to prevent mud, gravel, etc., from mixing with the ore when subsidence takes place. The legs of the setts are blasted out and the overlying burden is lowered, as a consequence, all over the area in question.

Mining below this is now done by the real caving system. The miners drop down 12′ or 15′, depending on the hardness of the ore, and run a drift as before. Side rooms are run to foot and hanging walls and when these are reached the most remote setts are blasted, and the roof is caved in. By working as they retreat practically all the ore is removed from beneath the lagging above, only one sett being usually blasted at a time. Sometimes several rooms are worked out before caving, but it is unsafe to leave them for any length of time. It is deemed advisable to finish one room before beginning another. In this manner a whole slice is taken out, and overlying debris or "gob" is lowered once more. Then a drop is made for another and another slice, until the bottom of the deposit is reached.

Contrary to what might be expected this is a comparatively safe method of mining. The men work near the back all the time, and, should there be any danger, warning is given by the gradual crushing of the timber. No large rooms are excavated at any one time, and there is practically no danger from this source.

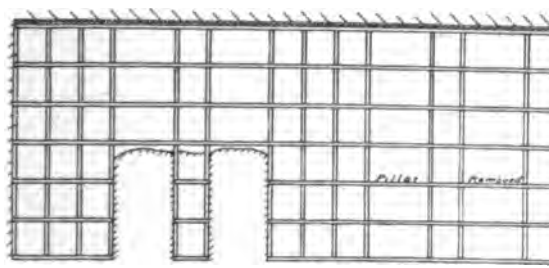
The system is also cheap, comparatively little timber is used, and even that is of an inferior order. Very little powder is necessary, and there is not much drilling done. Holes are drilled with machines, augurs, or hammer and drill, as the particular hardness of the ore may make advisable. The cost of mining is low, and contracts run at $4.50 for an 8′ x 8′ drift per foot of advance. The miners make from $55 to $60 per month after deducting all expenses for powder, caps, fuse and candles.

Queen Mine, Negaunee, Mich.

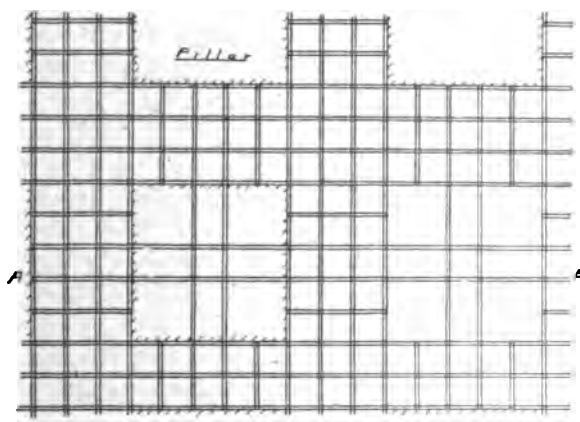
In the Queen Mine, as its name implies, we have a fine example of systematic iron mining. The ore body is large and fairly regular and lends itself particularly well to methodical development. The ore is not very hard, and it is not soft enough to cave, as in the Hematite. A special method has been adopted and seems to answer the purpose very well. The system in vogue starts out as a square sett system and develops a caving system as the work proceeds.

The ore body is in the shape of a lens, and dips to the north at an angle of 38°, and also pitches to the west at 45°. Six shafts have been sunk, the first three on the eastern side being now worked out. From the shaft a well laid out system of haulage ways has been driven, special attention being given to prevent interference of cars with timber and vice versa. The timber can be handled on one line of tracks often at right angles to the haulage tunnels. The main ore drift has been double tracked, and an endless cable picks up the

loaded cars of ore as desired, and takes them to the shaft. The cable is operated by an engine at the shaft with a special device to keep up uniform tension. The cars are attached to the cable, which is always moving, by hand, and are detached automatically when they reach the shaft. They are dumped into pockets and sent back by the cable on the other track. The expense of operating this haulage system is only ½ cent per ton.



Vertical Section Through A-B.
Fig. 22.



— Plan of Stope, Queen Mine —
Negaunee, Mich.
Fig. 21

Coming now to the mining system proper, we find a face of 3 setts wide or 25′ carried forward, and timbered with good substantial square sett timber. Then parallel to this another similar face is driven, but with a pillar 5 setts, or 40′, left between. Crosscuts are also run blocking out the pillars into squares. (For plan and

elevation of stopes and pillars see Figs. 21 and 22.) At the same time these faces are being worked on the level, another and another slice is stoped out and timbered above. In this way the ore body is honey-combed to the top of the deposit, pillars and rooms alternating throughout the level.

After the ore has been excavated in this manner the work of taking out the pillars and caving begins. A raise 8′ x 8′ is now run up through the centre of the pillar, and timbered with the usual setts. Thus between the centre sett and the timber in the rooms outside, there is a distance of two setts. The top of the pillar is taken out to the depth of one sett, and caps of double length are used to connect the centre with the outside setts. This is done on the four sides and the top heavily lagged. The ore is then worked downward using the long caps at each step, but without lagging. The material of the pillar is readily broken up and sent down the chutes in the outside setts; in fact it is the most rapid method of breaking ore in the mine.

When the pillars have all been robbed the tracks are taken up, a flooring of poles is laid, except where there is a rock floor, and every second leg is blasted out, thus bringing down the whole mass of timbers as well as the roof.

A system called "scramming" is used to mine on the level below. The level is divided into 50′ squares, and in each a raise 4′ x 9′, in two compartments, is run up to the lagging above, the levels being 85′ apart. Starting 9′ down a drift is driven from the raise 25′ each way, and timbered with light setts. The ore is shovelled directly into the chute or a wheelbarrow is used. A second drift is run beside the first, though not always, and the bottom is lagged over. Then the legs are blasted, and the overlying debris caved, as in the Hematite Mine. The process is repeated until the 2,500 sq. ft. is lowered 9′. The miners now drop once more, and repeat the operation, and so work down to the level.

While work is progressing in the drift the timbers begin to crack, which is a good sign, because it shows that the mass above is slowly settling. If the timbers do not show that they are supporting great weight the debris has become "hung up," and is liable to come down at any moment. Seeing this the miners either blast it down, or get out of the place. When the timbers show pressure the workmen are safe, as the mingled rock and timbers settle very slowly, an inch or so a day.

This method of scramming is also used in new workings under gravel, sand or loose rock. In that case great pits are formed on the surface immediately above.

In the foregoing description of these several mining methods, little attempt has been made to go into the minute details of the various schemes presented. The systems taken up represent the actual practice, in their most essential features, of underground work in Western America, outside of coal mining. Much more might be said in regard to many matters connected with them, such as their comparative expense, the percentage of ore recovered, their suitability to general conditions, etc. To go farther into these matters would make the paper unduly long. No references have been consulted, as the data have all been gathered by the writer at first hand.

PAPER No. 205

MINE TIMBERING IN SECTION 16 OF THE LAKE SUPERIOR MINING COMPANY, MICHIGAN.

By C. St. G. Campbell, S. Can. Soc. C. E.

In the following paper it will be necessary to depart somewhat from the subject proper and give a brief description of the location of the mine, the method of mining the ore, the management, etc.

Section 16 is essentially a hard ore iron mine, situated three-quarters of a mile from Ishpeming, a town fifteen miles from Marquette, on the south shore of Lake Superior.

The mine is worked chiefly for hard ore, there being three large lenses, each of a different grade, according to the percentages of iron and phosphorus contained. There are also two "pockets" of soft ore, which is locally known as "Haematite," but after mining these "pockets" for some time, it was found that the ore was too high in phosphorus to compete with the soft ores of the surrounding mines. So, for the present, at least, the mining of it has ceased.

The hard ore is found with a foot wall of decomposed Diorite, resembling soapstone, and a hanging wall of quartzite or jasper. A great dyke of Diorite cuts across the deposit and makes the formation somewhat irregular. The three lenses dip at average of 70° with the horizontal. They have an east to west strike and vary very much in their dimensions; ranging from 10′ to 700′ long. The dimensions of the so-called "South vein" have not yet been determined, as it reaches below present operations.

The method of extracting this hard ore is as follows: At intervals of 60′, levels are run out from the vertical or hoisting shaft until the ore is reached. A tunnel is cut along the length of the lens, clinging to either hanging or foot wall as the case may be. Raises are then made every fifty feet to the above level or nearly so, a back of fifteen feet being left to make tramming safe. Through this back a small hole is cut to let down timber, also for the purposes of ventilation, etc. When first cut, these raises are nine feet in diameter and are afterwards widened until the dividing pillar is as thin as is consistent with safety, say 15′ in the average.

The next step is, in many ways, modified by the width of the lens, but it suffices to say that the stope is carried across the width of the vein, the shift boss using his own discretion as to the

method employed. Finally, however, the stopes or raises are filled up with rock, leaving a timber tunnel for the passage of trams on the level below. Mills are also built and rock filled in around them, a process which will be described more fully later. The pillars are then mined out and the places where they were filled in with rock. In this way all the ore is secured.

The "Haematite," so-called, is mined by the "square set" system, which consists of taking out slice after slice of the ore, the length and breadth of the "pocket," and in its place putting timber in the form of skeleton cubes, the sides of which measure eight feet. These cubes or "square-sets," as they are called, are put in one at a time, just enough ore being taken out to allow the erection of a single square-set. The pocket is worked from bottom upward, thus securing the advantage of gravity for the removal of the ore. All the ore is sent down by means of improvised chutes made of lagging.

The mine is at present 850′ deep and the shaft is still being sunk to tap the south vein. There are at present thirteen levels, twelve of which open on to the shaft. The 4th, 5th, 6th, 7th and 8th levels have all been mined out even to the pillars. On the lower levels, tunnelling and raising are being carried on, while on the first three levels, the "robbing of the pillars" is not yet completed.

There are two other shafts, besides the one above mentioned. These are used for ventilation and shooting down the rock used for filling. These shafts, one of which is inclined, reach only to the second level. From there on, the rock is sent to the lower levels by means of mills.

For the most part, the "Hard Ore" justifies its name and is hard and compact, but occasionally it is of a slaty structure or full of cracks and fissures. In such places it is necessary to use drift sets. Similar protection is also necessary when drifting through decomposed Diorite, locally known as "Soapstone."

The proposition which the timberman has to handle, now having been outlined, the respective applications of the different methods will be taken up in detail.

The timber is obtained, for the most part, from lumber camps, the furthest not being more than twenty miles from the mine. This timber is taken to the mine by rail and stocked near the main shaft. Second class logs are used, knots and slight crookedness not being objectionable. The logs, cut into either 5½′, 8′, 10′ or 16′ lengths, are lowered into the mine by means of chains attached to the bottom of the skip. The timber men land them at the level station below with the aid of a rope, ship them on to a tram and take them to a timber-dock, where they remain until required.

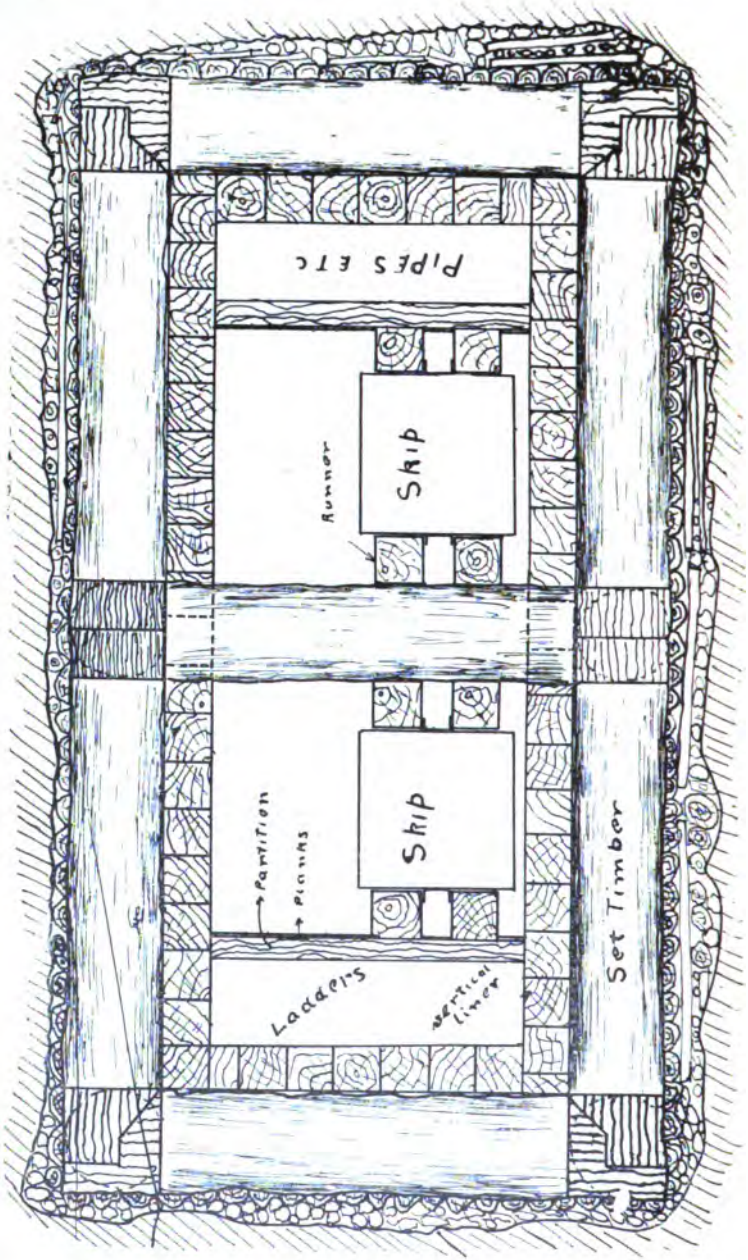
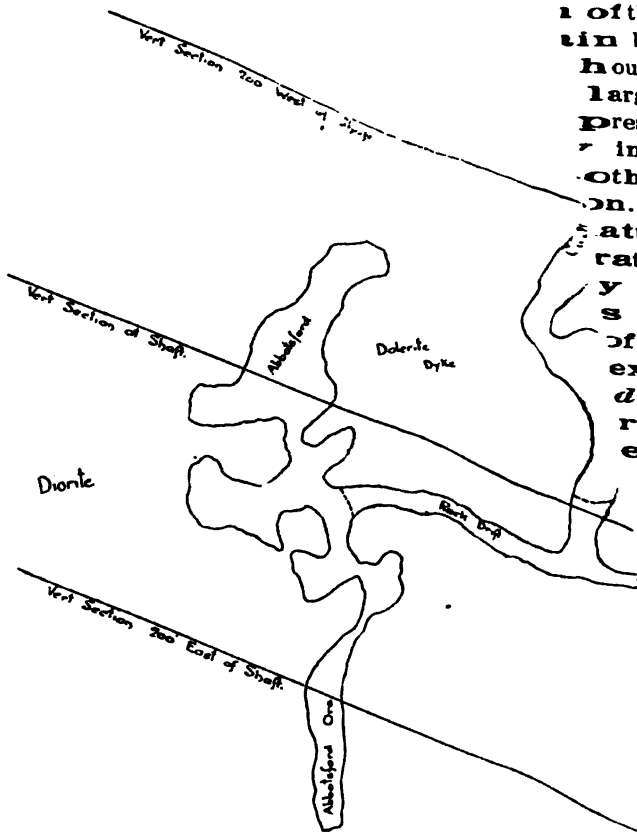


Fig 2:
Horizontal section through shaft.



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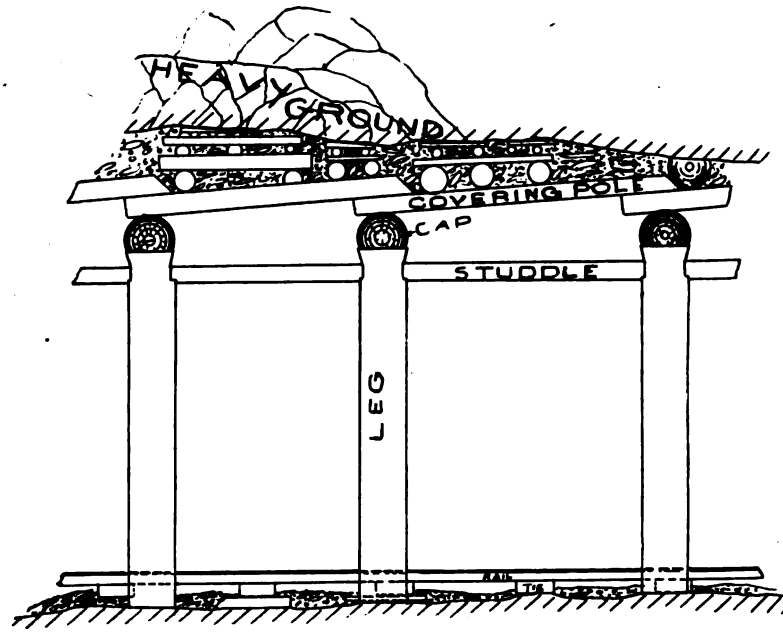
Between the hours of twelve and one on the day shift the miners are on the surface for lunch, and advantage is taken of this fact to lower timber. In consequence the timbermen remain below and take out timber, thus postponing their lunch for one hour. Hemlock and white pine are used for the most part in the large timbering. Cedar is used for lagging. The captain is at present experimenting on hardwood. Squared timber is used only in the shaft and under certain special conditions elsewhere. In other places not only is timber used round, but also with the bark on. The life of a "stick" is very uncertain, depending upon the nature of the wood, the stress to which it is subjected and the temperature, hence the moisture. On the 7th and 8th levels, immediately above the pumps, which are on the 9th level, the timber lasts only five months, after which it is quite easy to force the point of a candlestick six inches into the wood with the hand. This is exceptional, however. The average life of timber in the mine is *said* to be ten years. The timber is often crushed by the settling of ground, but there is little danger to life in this, owing to the slowness of settling.

SHAFT TIMBERING.

The method of sinking the hoisting shaft is somewhat similar to that of raising a square set. A rectangular hole is stoped down to a depth of 10′, having a width of 10′ and a length of 18′, and in this hole is set up a double square set, 8′ x 8′ x 16′. This square set is suspended from the ore above by means of bolts. It is then wedged into place and lagged between the timber and rock. The shaft is then sunk another 8′ and another double square set placed and bolted to the bottom of the former, and so the sinking and timbering proceeds. The timber in the square sets used is from 12″ to 18″ in diameter. Every time an advance of three sets (24 ft.) is made, the small shaft pump is lowered the same distance, so keeping within the 27′ practical pumping limit.

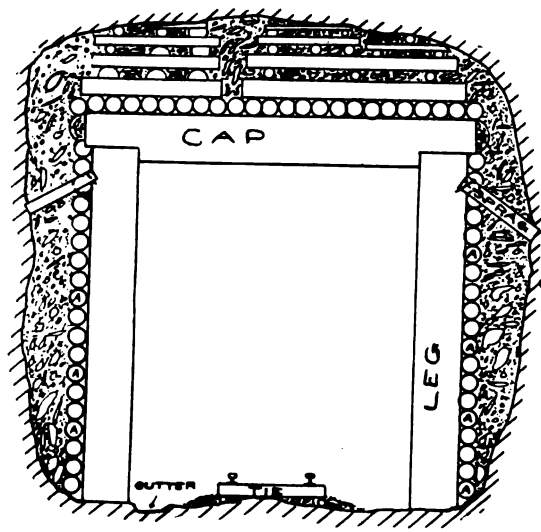
The shaft is then lined inside the square sets with 8″ x 8″ squared timbers, 18′ long, placed close to one another vertically, giving the shaft a box-like character. In each set and parallel to the ends of the shaft are placed cross-pieces to which planks are nailed, thus dividing the shaft into four compartments. The centre two are about twice the size of the end ones and are used for skip roads, while the end compartments are used for pipe, pumps and ladder ways. (See Fig. 2.)

The skips, which are steel boxes 2′ 6″ square and 5′ high, slide in runners which consist of four 8″ x 8″ beams, two at each side of the skip. These are placed vertically 6″ apart.



Side elevation of drift set.

Fig. 3 (a).



End view of drift set.

Fig 3 (b).

Until lately much trouble has been experienced from water in the shaft. In view of stopping this water downpour, troughs or garlands have been arranged to carry the water into pumps at depths of 190′ and 680′. This has proved very effective.

The rock shafts are very much simpler in construction, being merely lined with rough unbarked logs built up like a crib. It is usual to hoist to the surface all rock from the stopes at the bottom of the mine and send it down again to the levels where the pillars are being robbed. Obviously this supply of rock would be insufficient. Hence carloads of loose rock are brought from the No. 1 Hard Ore Mine and dumped down one or other of the shafts as required.

DRIFT SETS.

In running through Soapstone on the 2nd, 9th and lower levels, the back and sides of the tunnel are so weak that they have to be supported. This is done by means of "drift sets." Two trestles, five feet apart, each consisting of two legs and a cap, with a covering of poles resting on the caps, constitute for the main part what is known as the "drift set." The caps are chopped flat at the ends so as to set firmly on the legs. The pairs of legs are kept apart by studdles, which are poles 4′ 6″ long and 4″ in diameter, set close under the caps and at right angles to them. See Fig 3 (a). The legs are firmly spragged against the wall and spaces between the legs lagged on the rock side. The lagging is nailed to the legs horizontally, one above the other, and the loose rock is piled in behind the partition so formed. The covering poles used are from 4″ to 5″ in diameter. These are laid lengthways, the ends of the poles in one direction of a set resting on a cap, and in the other direction resting on the ends of the poles of the preceding set. By means of small pieces of timber the back is caught up and wedged tightly. See Fig 3 (b). If the pressure is likely to be great, owing to caving in of the sides of the tunnel, the legs are set wider apart at the bottom to ensure greater stability. At each end of a line of drift sets, slanting props or "rakers" are propped against the legs to keep the whole steady when the blasts go off. See Fig 3 (c).

SQUARE SETS.

A single square set consists of four vertical legs arranged in an 8′ square, each leg being 8′ high. The legs of two opposite sides of this square set are held together by caps, which rest on the top of the former. The two other sides are held together, or better still, held apart, by studdles, in this case 8″ to 10″ in diameter. The studdles are nailed in place a little lower than the cap. The

legs and caps have average diameters of 18″ and 12″ respectively. The top of each set is covered with 4″ poles, in order to prevent ore from coming down on top of the miners. The whole set is spragged securely when first built and thus remains until surrounded with other sets. For the sake of strength and continuity, the same two sides of a square set always have the caps. If the stope

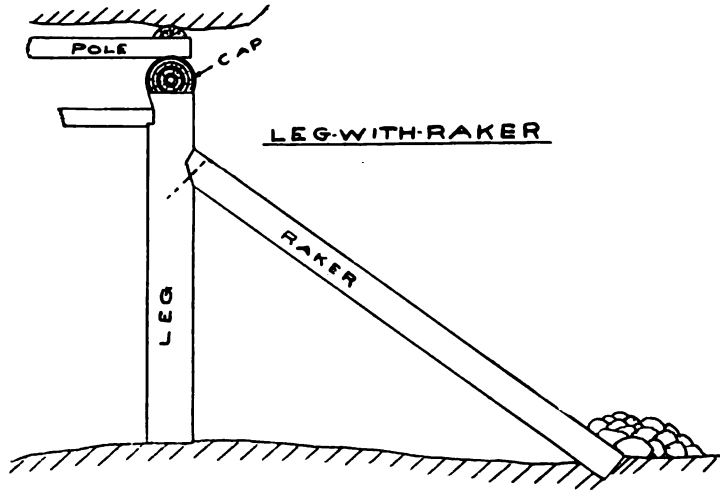


Fig 3 (c).

is fairly wide and high, chutes are built in so that each one is fed by five columns of sets. Twice has an attempt been made to mine the hard ore by this system, but without success.

STULLS.

In raising up along the lens the hanging wall is often loose, great masses sometimes breaking off, and, in consequence, it is necessary to prop the loose ground up by means of stulls. See Fig. 4 (a). A stull is a single stick of timber varying in size according to the stress to which it is subjected. The distance is measured from foot to hanging wall and the stull cut a corresponding length. A socket is made for the end of the stull on the foot wall by scooping out a shallow hole. The stull is then driven into place and fixed tightly by means of wedges. For obvious reasons, every endeavour is made to have the greatest stress along the line of the prop, though in some cases this is not at all possible. See Fig. 4 (b).

In the raises on the 13th level, it is impossible to set up machines, owing to the narrowness of the lens and the steepness of the dip, except as follows: Two stulls are erected within 7′ of the breast on either side of the raise (8′ apart). On the top side, poles are laid halfway up to the hanging and then ore is pulled down behind these poles until a horizontal surface is obtained. On this surface, which is about 6′ wide by 9′ long, the machine is set

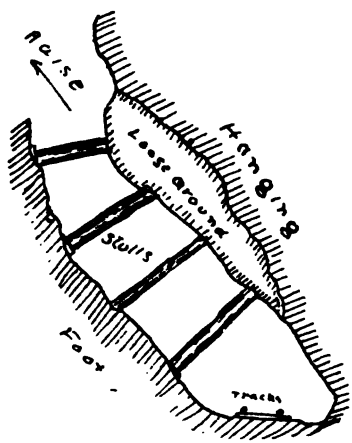


Fig. 4 (a).

up. See Fig. 4 (c) This is called a bench and is used for 16′ of advance stoping, after which another one is built above it in the same manner. It is found expedient to remove the lower ones as soon as the top ones are built, to give free passage for ore.

Great difficulty is experienced in getting timber up into the raises. Owing to oversight, all the tackles are too short, so the logs have to be carried up the slope by the timbermen, who hold the log under one arm and use the other to pull themselves up. It is quite customary to do this for 30′ before the tackle comes into play.

"TIMBER PILLARS," OR CRIBS.

The duty of a timber-pillar is to "hold up ground." It serves the same purpose as a vertical stull, only on a much larger scale. The pillar is made of rough unbarked logs, 8′ in length and anything from 6″ to 2′ in diameter, according to the weight the pillar is to bear.

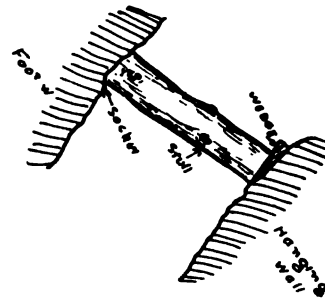


Fig. 4 (b).

A pair of such logs, 7′ apart parallel to each other, are laid directly under the "bad ground" and on top of these are laid two more at right angles to the first two, the same distance apart and parallel to each other. Again on top of these are laid two more in the same way. The pillar is thus gradually built up to the back and eventually wedged down tightly by lagging and small pieces of wood. Considerable experience is required to make a tight fit, owing to the unevenness of the ground and the tendency

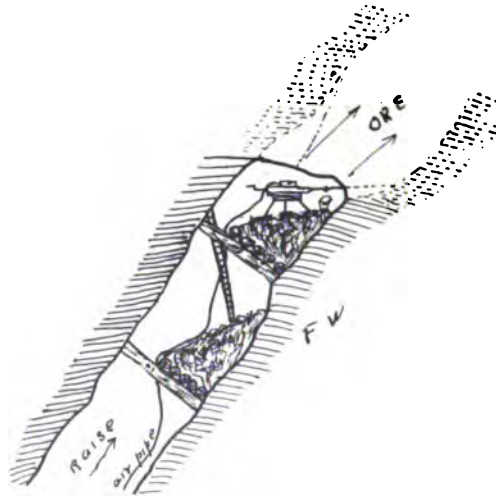


Fig. 4 (c).

for the whole to shift. All the pillars are inspected every day by the timber boss to guard against any such failure. In laying one cross-piece on top of another there is great tendency to roll, in consequence notches or "joggles," as they are called, are cut in the lower log, into which the upper one fits. It is not usual to cut them more than 3″ deep.

Wooden pillars are used nearly altogether in the robbing of the ore pillars in between the stopes. These ore pillars are about 25′ through from stope to stope. A space is cut out of the pillar,—about 9′ through and the width of the lens, if the same be narrow—and 8′ high. As many pillars as can be are built in this space, three feet always being left between them for walking roads. Sometimes, instead of making two pillars of the foregoing dimensions, one long pillar is made 16′ x 8′. The inside of the timber pillar is now filled with loose rock. This rock steadies the pillar and takes the bulk of the weight when the back settles. The long pieces are called "edgers" and the shorter ones "cross-pieces." When these pillars are securely wedged against the back, the machines are set to work again and a space similar to the first is mined out and treated with pillars. This process is carried on the width of the vein and breadth of the ore pillar until all the ore in the latter rests on timber. The stopes on either side are now filled with loose rock to the level of the top of the timber pillars, likewise the spaces in between the pillars, and the process of mining out and timbering proceeds as before, the timber pillars having as their floor the tops of pillars of the slice below. The level of the rock in the stopes is kept up to the bottom of the timber pillars.

"DOCKS."

The purpose of a "dock" is to hold back rock. It is used where loose rock is pouring down upon the track and so stopping the trams; likewise in filling the stopes, as before mentioned.

The dock is a simple cribwork like the timber pillar. Rock is dumped inside and then the running rock is allowed to bank up against it. The double length 16′ is more usual than the single in docks. To save timber and labour the inside edgers are sometimes done away with, the ends of the cross-pieces resting on the outer edger and on the sloping pile of rock. As the work progresses, a couple of men shovel down rock and thus keep the level of the rock up to the required height for the cross-pieces to rest upon. (See Fig. 5.)

In filling the stope a tunnel must be left for the trams, hence on both sides of the track, docks are built to a height of 8′ and are

filled with rock in and behind. A double layer of covering poles, 4″ in diameter, are laid across from one dock to the other and the whole is filled over with rock. It is considered advisable to leave ample space overhead in the tunnel, because the pillars sink sometimes three feet or more, owing to the settling of the rock filling. It is found that the hanging-wall side settles much faster than the foot-wall side.

The spaces between the logs are stopped up with "filling pieces," to prevent the rock from coming out into the tunnel.

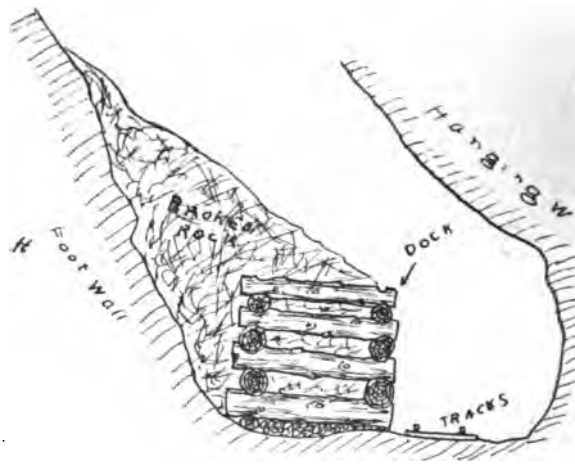


Fig. 5.

MILLS.

Mills are used in robbing the pillars, to convey to the level below the ore which is mined. A mill might be called the converse of a timber pillar. It is cribwork built up like the other, but is not filled with rock. Instead, the mill is covered with cedar lagging on the outside and filled around with rock.

The mill is built in the same relative position to the tunnel as the dock. As the ore is taken out above, it is dumped into the mill, coming out into a tram in the tunnel by means of a chute.

The mills are made either single or double, being 5′ 4″ x 5′ 4″, or 5′ 4″ x 10′. The latter is the more usual form, one compartment being used for a ladder road, the other to dump rock down.

I.

Section 16 Shaft-house. Notice the steam shovel and the ore dumps.

II.

This is a typical mill chute. Notice the extra cross-piece for the double-mill ; also the pike and tram-bar beside the track.

Filling pieces are used in the partition of the double mill to prevent rock from coming into ladder-road. (See Fig. 6.) There is an enormous wear and tear on the mills due, to the falling ore, hence the soundest timber is used. Hemlock is preferred owing to its toughness.

The life of a mill is very uncertain. As an average, a mill lasts three months when it is worked night and day for six days each week. What happens is that the pieces of ore cut through the cribbing pieces, attacking all sides of the mill impartially. To repair a mill, it is lined with ¼″ 4′ x 6″ iron plates for 20′ down and then with 3″ planks. The wear and tear depends upon the height of the

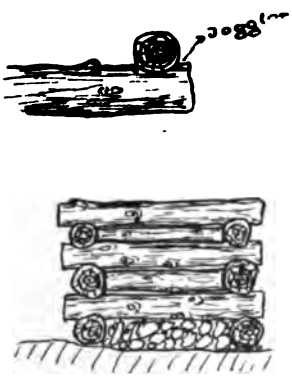


Fig. 6.

mill, the kind of timber and the nature of the ore. The diameter of the pieces of timber is from 10″ to 18″.

It is customary to give an inclination of 15° to the vertical, to the mill, in order to break the fall of the ore and so save the bottom boards of the chute, and, incidentally, insure safety for trammers.

CHUTES.

The chutes that empty the mills are 2′ wide at the smaller end, widening out to 4′ and covering all the floor space of the mill. They have an inclination of 45°, the mouth is 4′ 6″ from the track and protrudes 1′ into the tunnel. All chutes are made of 3″ x 8″ planks. Spaces are cut out of the cribbing pieces of the mill to permit the chutes to be made. Chunks of ore, 8″ or less in diameter, can get through the chute, anything larger than this sticks and has to be

"block-holed." This is to be avoided, because the blasting soon destroys both mill and chute. (See Photo II.) In the case of the square chute, the ore is never allowed to fall directly into the chute from any height over 8′, as will be seen, the inclined lagging in each set acting as a sort of chute.

The ore is kept back by means of boards fitting into slits in the sides of the chute. Sometimes it is hard to send these planks into place and so complications arise.

STAGING.

When it is necessary to take ore off the back of a high stope, the drilling-machine has to be raised within a few feet of the place to be mined. This is done by means of staging. A stage consists of three ladders, each at the apex of an equilateral triangle of 5′ side. The ladders are inclined outwards and are wedged against the back. Planks are then placed on the rungs of the ladders, so as to make a platform. The machine is then set up on this platform. At the best it is a very shaky affair and cannot be carried to any great height; 15′ being considered a very good height for the platform of such a stage.

LADDERS AND SOLLARS.

In this mine the ladders all have an inclination. This inclination tends to make climbing much easier and safer. The poles of the ladders are made of 3″ x 5″ white oak scantling. The rungs or "staves" are either of white oak or iron, the former being 1½″ in diameter, the latter ¾″ in diameter. Under the calked boots of the miners they are soon worn through and are in many cases left too long for safety.

The shaft ladders are in sections of 20′. The sollars are 15′ apart, with a hole in each large enough for a man to get through with ease. The end of the ladder protrudes through the hole.

The ladders in other parts of the mine, in the other raises for instance, are much longer and are made by bolting together two or more 20′ lengths with scantling, on the outside. The ladders are always spragged securely to prevent shaking.

The sollars are a great means of safety and prevent many serious accidents, especially in the shaft, where it is now impossible to fall more than 20′, in the ladder road, that is to say.

MISCELLANEOUS.

The timber-gang in full force is eleven strong, counting the boss. Below is a classification of the men in the mine.

Captain..	$4.50 per diem.(?)
Shift-bosses..	$2.50 " "
Timber-bosses..	
Barn boss..	$2.30 " "
Timbermen. ...$1.85 to	$2.00 " "
Miners..	$2.10 " "
Helpers to Miners..	$1.85 " "
Contract shaftmen.. ..	(Paid per foot of shaft sunk.)
Ore trimmers..	$1.85 per diem.
Rock "	
Pumpmen..	Amount of wages not ascertained.
Track-layers..	
Skip tender..	
Track cleaner..	

The tools of the timber-gang are few. The following is a list of their whole outfit :—

Wax candles ..5 per day of 10 hours.
Two saws .. ..hand and cross-cut.
Axes.. .. .. ..one per man (used also as hammers.)
Spikes .. .. ..various sizes, (1″-12″ long.)
Ropes. . .. .. " "
Chain. . .. ..8′ long.
Timber truck.
Log pike.

The foregoing information was obtained by the writer at Section 16 Mine last summer. The figures given are, to the best of his knowledge, accurate. However, the character of the mine is such that rules of thumb are few and far between. When a problem presents itself, it is solved according to the ideas of the particular shift-boss in charge, subject to the approval of the captain, who makes his rounds every morning. In conclusion, the writer wishes to acknowledge the kindnesses extended to his party and himself by the officials of the Lake Superior Mining Company during their stay in Ishpeming.

DISCUSSION.

Mr. Carlyle. Mr. E. J. Carlyle asked how, in a system of square setts in a large vein, timber connections were made between levels. The sills and timber of the upper level would, he thought, have to be very carefully approached, and he wished to know how the setts of the lower level were connected with those of the level directly above.

Mr. Parlee. Mr. Parlee replied that in connecting up timber between levels, it was considered good practice to have sills of the level below, in the same vertical plane with those above, surveyed and laid down accordingly, but in carrying up the setts 100 feet, it was almost impossible to go up straight enough to have post match with post properly. They would either come one side or the other of the vertical plane and be out of plumb perhaps a foot or two. Unless they could meet the upper setts exactly, it did not really matter whether the sills below were surveyed or not, except to get the general direction of the timber. The sills of the upper level were caught up by the cross timbers, reaching two or three sills. Little attempt was made to have posts of lower setts directly under posts of upper setts. Bulkheads were often used and the rock must be blasted out carefully and not too fast.

Mr. Webster. Mr. G. Webster asked whether, in the "Old Ironsides" mine, the "V" shaped chutes did not run the full length of the slope, and was answered in the affirmative.

Mr. McMurtry. Mr. G. O. McMurtry said that in the Queen mine, the square sett system was only used underneath the hanging wall. Raising and top slicing were used as well.

Mr. Parlee. The author replied that the square sett system was used wherever the ore was too hard to cave without it. It was not the intention in the paper to discuss all the methods used in each mine, but only those especially valuable. Different methods might be used under different conditions.

Mr. Webster. Mr Webster asked if in Section 16 mine, the raises for chutes were vertical or inclined?

Mr. Campbell. Mr. Campbell answered that the chutes were inclined at an angle of 15 degrees to the vertical.

Dr. Porter. The Chairman remarked that the papers had covered or attempted to cover a very important part of the mining industry, and a great deal could be brought out by a more detailed discussion, and he sincerely hoped that the members present and others of the Society would write Mr. Parlee, Mr. Campbell or himself, asking

questions and bringing out differences in practice in different mines. The information that could be so secured, would add considerably to the value of the papers. Dr. Porter.

What Mr. Parlee had said about the impracticability of exactly connecting the timbering of adjoining levels held true in all parts of the mining world. The theory was that posts in successive level should come under one another, and in certain mines that he had visited, more or less successful attempts had been made to do this, but in most cases, the method described by the author had to be adopted. As Mr. Parlee had said, the main thing was to see that the vertical lines were kept true and that the timber was put in substantially. Sometimes comparatively heavy bulkheads were used. It was, of course, possible to survey with sufficient accuracy to have the posts placed perfectly plumb and in line, but this was too troublesome, and it was still more troublesome to erect great masses of setts exactly in line and plumb, especially when, as was frequently the case, there was movement going on in the ore body or hanging wall.

The criticism made by Mr. McMurtry with regard to the Queen Mine, he thought, was correct, but Mr. Parlee had correctly described the method employed in a considerable part of the mine, and had mere omitted to discuss other methods also in use there in different ground.

General Section.

President—G. A. Mountain.
Vice-President—W. McLea Walbank.

A meeting was held Thursday, March 3, 1904, and a discussion took place on Mr. J. A. Jamieson's paper on "Grain Pressures in Deep Bins." (See Vol. XVII. Part 2.)

A Business Meeting of the Society was held on Thursday, March 10, 1904, Mr. Walbank in the chair. The following presentation to the library was reported:—

"De Pontibus," by Waddell, presented by Mr. J. A. McMillan, M. Can. Soc. C. E.

At the close of the business meeting the discussion on Mr. J. A. Jamieson's paper was concluded. (See Vol. XVII. Part 2.)

Mechanical Section.

Thursday, March 17, 1904, Mr. K. W. Blackwell in the chair. The following paper was read by the author:—

PAPER No. 206

THE HYDRAULIC DREDGE "J. ISRAEL TARTE."

By A. W. Robinson, M. Can. Soc. C. E.

This dredge was placed in service in June, 1902, in deepening the channel through Lake St. Peter in the River St. Lawrence. As it involves some new features both in design and mode of operation, and has achieved a remarkable result, a detailed account of the dredge and of the work on which it is engaged will be of interest.

The author has purposely refrained from publishing an earlier account of it, preferring to wait until it has been thoroughly tested in service, and the results made available. The present paper will deal with the conditions leading up to the construction of this dredge, a description of the dredge itself, and a statement of the results accomplished.

The Lake St. Peter Channel is part of the improvement in navigation of the River St. Lawrence between Montreal and Quebec. This work has for its aim the passage of ocean vessels to Montreal, making that city the point of trans-shipment of the inland lake and rail traffic by the St. Lawrence route to the sea. This section of the river is 160 miles long between the cities named, of which about 60 miles is dredged channel in about 20 different places.

The kind of material met with, varies in the different localities from soft clay to slate rock and stones. The dredging machines, therefore, must be different in their character for the different sections of the work.

The original least depth of water in the channel was 10 ft., this being the nearly uniform depth on the flats of Lake St. Peter, which is a shallow expansion of the river about 9 miles wide by 18 miles long. The bottom here is of blue clay of a varying degree of softness, with some sand and stones in places.

For the information of those unfamiliar with the subject, the following table of the successive stages of water attained, and the dates of completion, is appended.

Original depth of water in channel..	10 ft.
Dredging commenced in 1832.	
Depth completed in 1853..	16 "
Depth completed in 1858..	18 "
Depth completed in 1865..	20 "
Depth completed in 1878..	22 "
Depth completed in 1882..	25 "
Depth completed in 1888..	27½ "
Depth now nearly completed...	30 "

The fact that this great work was commenced in 1832 and prosecuted with more or less continuity ever since, is eloquent testimony alike to the importance of the work and to the energy, pluck and perseverance of those early pioneers who so boldly faced a work of such stupendous magnitude with the primitive appliances and slender financial resources which they then possessed. It is indeed a fortunate fact that all this early work still remains to the good, and that the character of this noble river is such that its bed is practically unchangeable. In this respect it is unlike the alluvial Mississippi, which requires a fleet of ten powerful dredges to maintain the channel. It is strange that in the public mind, unacquainted with the facts, there exists a widespread impression that much of this dredging is of a temporary nature and that it must naturally fill in again. This is entirely erroneous. The geological formation is such that there is practically no erosion of the banks, and the bed of the river is composed of various kinds of material, some of which is very difficult to dredge, and all of which (with the exception of one or two unimportant places where sand occurs) remains in place. Surveys and soundings made sixty years ago correspond closely with those of the present day. The work, therefore, is permanent.

The size of ships using the St. Lawrence route has steadily increased and has at all times been fully up to the limit of the depth of water. In a paper on "The Economy of Large Ships," read by the author before the Society in 1902, he pointed out that when the 30 ft. channel of the St. Lawrence was completed, it could be navi-

gated by a vessel 520 ft. long, 61 ft. beam and 12,000 tons dead weight carrying capacity (or about 20,000 tons displacement), and that the economy of such a vessel was nearly double that of a vessel of 5,000 tons dead weight. It follows that a larger vessel would be still more economical, the limitations being only depth of channels, capacity of harbours and facilities for furnishing and handling large cargoes.

In the same paper he pointed out that a greater degree of safety and immunity from accident would be obtained by a large vessel than several small ones of equal capacity. One of the reasons for this is that a large vessel, such as we have under consideration, will usually be commanded by higher salaried and more competent officers than a smaller ship or tramp vessel. This means that the accidents, due to ignorance or negligence, and which may be classed as avoidable, will be reduced. There are also risks of the sea, which may be classed as unavoidable. These will also be less with a large ship than with a small one, for the reason that the large ship does the work of, say, three small ones, or, in other words, carries as much cargo in one voyage as the smaller vessel will do in three. Consequently, the risk from unavoidable disasters is one-third in point of time of exposure to such disasters for a given amount of commerce, and furthermore the large ship is more staunch and seaworthy, and thus better able to withstand the stress of the sea.

The assertion that better paid and more skilful officers and crew of a vessel carry with them greater immunity from accident, is borne out by the history of the lines coming to Montreal, as comparatively few accidents happen to the large and well-appointed regular liners whose officers and crew are experienced in the service. The majority of the accidents are those which have happened to the smaller class of vessels, and are due either to inexperience or negligence.

In pursuit of great economy and money-making capacity, the size of vessels is ever on the increase. Hence the necessity for deeper channels and greater facilities for handling of cargoes. Many vessels are in use larger than the size above, and the limit of depth for a first-class ocean port is now from 35 to 40 feet.

The condition of the St. Lawrence ship-channel, in 1901, was that the much-to-be-desired 30-foot stage of water was still some distance off. There remained some 25 millions of cubic yards to be dredged, (*1) and the fleet of six large dredges were removing it at the rate of about 2½ million yards per season (*2). In order to meet the

(*1.) See Estimate 30 foot channel Dec., 1902; Annual Report Dept. Public Works, p. 146.

(*2.) The total number of cubic yards dredged in year ending June 30, 1901, was 2,479,385 cubic yards. See Annual Report 1901, p. 186.

FIG. 1.

ELEVATOR DREDGE ABERDEEN.

DREDGE "J. ISRAEL TARTE" AT WORK.

demands of commerce and to complete the 30-foot stage as early as possible, it was evident that something must be done to hasten the work. A large part of the balance remaining to be done lay in the soft clay of Lake St. Peter.

The existing channel through the lake was 300 feet wide in the straight portion, and 27½ ft. deep (or 26.1 at new datum of extreme low water, See Note) and about 18 miles long. The immediate work to be done was deepening to 30 ft. and widening to 450 ft. To allow a little margin the actual cut taken out in the deepening was about 5 ft., and the thickness of cut in the widening was 18 ft. to 20 ft. In the bends the width increases to 700 ft. The total volume to be removed to accomplish the deepening and widening in Lake St. Peter alone was, therefore, in the neighborhood of 15,000,000 cubic yards. To remove this at a much more rapid rate than was heretofore possible, the then Minister of Public Works, the Hon. J. Israel Tarte, after investigating the subject, resolved on the adoption of the hydraulic type of dredge, and the writer was commissioned to design a dredge that would have a working rate of 2,000 cu. yards per hour.

These instructions were given in February, 1901, and it was desired, if possible, that the dredge should be in operation by the end of August of the same year.

The conditions which presented themselves were as follows:

A channel 26 ft. deep at low water, about 300 ft. wide in the straight part and 600 ft. in the bends, and 18 miles long, with 10 ft. to 12 ft. of water on the banks. The section to be removed was that due to deepening the present cut 5 ft. and widening it 150 ft., and material blue clay of a varying degree of softness with some sand and stones in places.

The dredge, therefore, must fulfil the following conditions :—

1. It must be able to make a cut 700 ft. wide at one time and 5 ft. to 10 ft. thick at one cut.

2. It must leave a clean and level bottom and cut mechanically the entire area, as the material is blue clay and will not run or wash like sand.

NOTE. This work to 1897 was done to ordinary low water datum. Since that date a new datum 1.4 ft. lower has been established, which corresponds to extreme low water, a stage that has only once been reached in many years. The new channel of 30 ft. is therefore 3.9—or say 4 ft.—deeper than the 27½ ft. channel. In all ordinary seasons and except for a few weeks in the fall of the year the depth of water is 2 to 5 ft. above low water, so that a vessel of 30 ft. actual draft can safely navigate the 30 ft. channel except for a few weeks in the fall of the year if the season should be a dry one.

3. It must deliver the material sufficiently far to one side of the channel to avoid any risk of washing back again.

4. The floating pipe-line must be so arranged that it will freely permit of the movements of the dredge, and that it will withstand the winds and waves due to the locality, which are severe at times.

5. The dredge must be so worked that it will not obstruct the channel for passing ships.

6. The anchorage and movements of the dredge must be so arranged that the feed will be continuous and uniform.

7. The capacity to be a working rate of 2,000 cu. yards per hour.

8. The dredge must have ample coal supply and provision for a double crew.

The dredge "J. Israel Tarte" was designed to fulfil the above requirements and was built by the Polson Iron Works, of Toronto, Ont., and delivered and tested in October, 1901. The contract price was $163,800. This price did not include the discharge-pipe nor winches, which at the time the contract was placed, were not designed. In point of fact, when the contract was placed, nothing of the detail shop drawings of the dredge were made, nor any patterns available. In order to save time the contract was based on a general specification and outline design, leaving the details to be supplied afterwards as the work progressed. All drawings and patterns of every detail of the dredge were specially prepared and all material specially ordered, and the time which elapsed between commencement of the drawings and patterns and the testing of the dredge under steam was eight months.

Before describing the new dredge, brief reference will be made to the existing fleet of dredges and a statement given of the record already established by them on Lake St. Peter.

The fleet of dredges previously existing and engaged on the ship-channel between Montreal and Quebec comprises six elevator dredges, which, taking hard and soft material together, took out 2,479,385 cubic yards in the fiscal year ending June 30, 1901, at a total cost of $128,259.17, or an average of 5.1c. per cubic yard.*

These dredges have been brought to a high state of efficiency, and are the improved development of the early dredges on the work, the first of which was imported from Scotland in 1832.

The work done on Lake St. Peter by the elevator dredges may be illustrated by the "Aberdeen." This dredge is illustrated in Fig. 1. The buckets have a capacity of one cubic yard each, and can work to a depth of 40 ft. Small wooden barges, holding 300 cu. yds. each,

*See Annual Reports, Department Public Works, 1901.

are used to take away the spoil, and one tug suffices to do the work, going out with one barge while the other is being filled, making a round trip of about 1 mile in about 15 minutes.

This dredge worked in Lake St. Peter for a short time in 1901, and dredged 120,600 cu. yards. in 21 days at a cost of $3,054.88, or 2.53 cts. per cu. yd. The actual working time was 246 hours, giving an average output of 490 cu. yds. per hour.

The new hydraulic dredge, having a proposed capacity of 2,000 cu. yds. per hour, would therefore be called upon to accomplish results much larger in quantity than anything that had been done before on the work.

As far back as 1886 one of the elevator dredges then in use made a record which stood alone. This was made by dredge "No. 9" which, while working in Lake St. Peter, accomplished 886,710 cu. yds. at a cost of $25,723, or 2.9 cts. per cu. yd. (*1.)

The excellent work already done by these dredges rendered the task of improving upon them, by the proposed hydraulic dredge, the more difficult. The records for economy already cited, which were made by dredges "No. 9" and "Aberdeen,' were indeed hard to surpass, and have been rarely surpassed by any dredges in the world. The new dredge would be more costly than its predecessors, and manifestly, unless it could show considerably better results, not only in quantity, but in economy, would not fulfil the expectations concerning it.

It was recognized that a hydraulic dredge of this type is a special tool, that is to say, it would not be capable of doing the variety of work that the elevator dredge can do, or work in very hard material. Nevertheless the magnitude of the work in Lake St. Peter alone, and other places where suitable material exists. was sufficient to justify the construction of the dredge.

The state of the art of building large hydraulic dredges at this time, showed that it was possible to employ pumps of large power and capacity, and to deliver material through floating pipe-lines to a distance sufficient to meet the conditions of the present case. The great dredges of the Mississippi River, (several of which were designed by the writer) contributed much useful data and experience. (*2).

There, dredges were able to maintain a capacity of 1500 to 2000

(*1.) See Reports Harbour Commissioners of Montreal 1886 p. 80. This cost includes operating expenses of every kind, scow and tug service and repairs, but not interest or depreciation.

(*2.) See Trans. Am. Soc. C. E., Dec. 1898. "Dredges and Dredging on the Mississippi," by J. A. Ockerson, C. E., for a full account of these dredges at that date. Much further development has since taken place, of which no full account has been published.

cu. yds. per hour deposited 1000 ft. The material was sand, the depth 10 to 18 ft., and the cut made was a shallow trench by straight forward feed. Sand, however, is easier to dredge than clay, and these Mississippi dredges only worked to half the depth and deposited the material at half the distance which would be required on St. Lawrence. Furthermoré, the Mississippi dredges only made a cut 30 ft. wide at one time, whereas it was here required to make a cut 700 ft. wide. It was necessary, therefore, to adopt a lateral feed instead of a straight forward feed, and also to apply mechanical excavation which would cover the ground. No hydraulic dredges had done any successful work in clay, and attempts in this material had been abandoned on account of the clogging up of the apparatus. No examples existed of long distance pipe-line dredges of large size which made wide cuts. Large dredges in America which discharged through pipe-line either anchored by spuds making a radial cut, or by mooring lines, making a straight forward feed. Sand-pump hopper dredge practice of European designs offered no useful points. Here was, then, the necessity for a new application of the hydraulic principle of dredging, the points of novelty being, 1st, the lateral feed of 700 ft. width, while discharging to a long distance through a pipe-line adapted to such movement; 2nd, cutting mechanically over every foot of the ground in blue clay, and to do this without clogging; 3rd, the construction of a pipe-line that would be capable of standing some stress of weather and wave-action.

To this extent, therefore, this dredge was experimental, and the present paper will describe the result of the experiments and the methods adopted to improve the detail parts after testing. The writer's observation of the elevator dredges in Lake St. Peter led him to conclude that here was a clay deposit which could be worked successfully by the hydraulic method if the proper apparatus for cutting or digging it were employed. The clay is of a soft, unctuous nature, sometimes partly silicious, bluish in color and of a character suitable for brickmaking, or pottery. It dumps well from the buckets of a ladder dredge and slides readily down the chute into the barges in chunks, frequently the whole size of the bucket and showing the markings of the rivets. The problem in the new hydraulic dredge, therefore, was to cut this clay regularly and uniformly and feed it into the mouth of the suction pipe without clogging. Once there, it would slide freely along and be discharged without difficulty, and by making the pipe of large diameter and the pump with passages of large section, the clay could go through in lumps even more readily than sand or finely divided material of like nature, which would tend to precipitate. Thus the hydraulic apparatus is used, not for dredging, but for purposes of transportation only.

In considering the question of capacity, the dredge was designed to have a theoretical rate of 3,000 cu. yds. per hour, and it was deemed that this would be sufficient to give a working rate of 2,000 yards per hour, including the delays incident to regular work, but not counting delays from exceptional causes, storms or repairs. This rate required a section of cut 5 ft. by 6 ft. by a feed of 45 ft. per minute, equal to 3,000 cu. yards per hour. It was, therefore, necessary to provide a cutter capable of dealing with that section and with plenty of margin to spare, and to provide means for feeding it 450 to 700 ft. across the channel at the required rate. As this involved traversing the entire dredge broadside at that rate, and dragging the

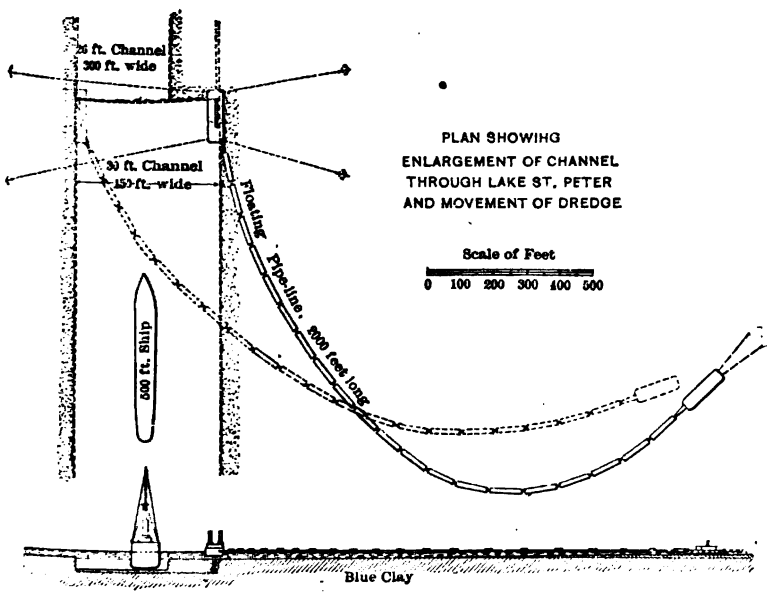


FIG. 2.

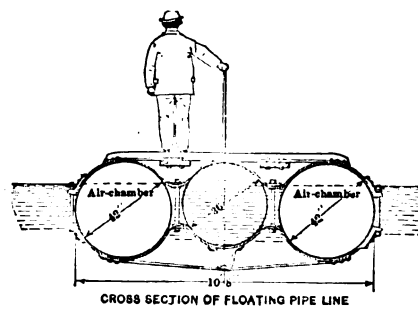
semi-submerged pipe-line after it, the power required for this purpose would be quite large, and produce a corresponding necessity of providing strong anchorage to the mooring lines, by which the traversing movement was to be effected.

In considering the movement of the pipe-line attached to the dredge, advantage was taken of the fact that there is a more or less constant current of ½ to ¾ mile per hour in the lake. This is due to the discharge of the river, and is modified by winds and sometimes by tides to a scarcely appreciable extent. The tidal variation at Quebec, 110 miles below, is 9 to 15 ft, but this gradually becomes less

on ascending the river until it becomes lost at the lower end of the lake. The current, therefore, causes the pipe-line to assume a catenary curve of varying tightness according to the travel of the dredge. This is shown by Fig. 2, which is a diagram showing the movement of the dredge and the relative position of the pipe-line.

The current, therefore, was employed to deflect the pipe-line to the form of a loop having slack enough to permit the dredge to traverse 450 ft. In order to utilize the current for this purpose, and at the same time render the pipe-line less exposed to the wind and waves, it was designed to be two-thirds submerged. The weight of a large steel pipe filled with water and mud is very great and would require very large pontoons to carry it in the air, but by partially submerging it the buoyant power required is much reduced.

The form of pipe-line adopted is that of a central conduit, 36 in. diam., carried by two cylindrical pontoons or air chambers 42 in.



CROSS SECTION OF FLOATING PIPE LINE

FIG 3.

diam., the three being bound together by truss-frames clamped upon them as shown in Fig. 3. In this way no bolts or rivets are put into the air chambers, and they may be readily taken apart.

The pipes were made up in 100 ft. sections and four sections of 50 ft. were made with the idea of putting them in that part of the pipe where greater flexibility was required. It was found, however, that these 50 ft. pipes did not stand the sea as well as the 100 ft. sections, and that moreover sufficient flexibility could be had without them. They were accordingly joined together and converted into 100 ft. sections.

The joints connecting the 100 ft. sections were at first made by uniting them with a forged steel pin-connection over the rubber sleeve, thus relieving the rubber sleeve of all strain due to tension of the pipe and permitting the required angular movement. These joints were not strong enough and were found to be too rigid in wave action,

and caused heavy strains to be set up, which broke some of the joints. They were temporarily repaired for the first season, and during the winter of 1902-3 new joints of special construction were devised by the writer designed on the ball-and-socket plan to permit of universal movement to a moderate degree, and also fitted with draw-bar springs to absorb the variations of length due to surging and pitching. The ball-and-socket principle was embodied, not in the pipe itself, but in a strong steel frame above the pipe, which was connected by rubber sleeves in the usual way. This has proved entirely successful and the practical result is that the dredge is capable of continuing at work in all but the heaviest weather. The general

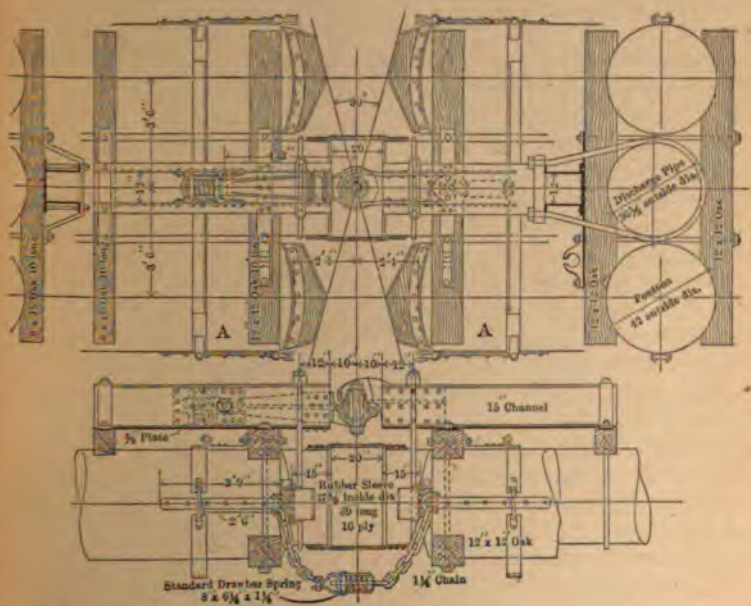


FIG. 4.

construction of the pipe-line and joints is illustrated in Figs. 3 and 4. The ball end of the joint is solidly riveted to the frames on the pipe, while the socket end is fitted to slide in a casing or frame, and its movement is resisted by springs, as shown. These springs are two in number and are heavy car springs. They are 6¼ in. diam. and 8 in. long, and made of round steel, 1¼ in. diam. The springs are carried between spring-plates, resting against stops in such a way that the springs are compressed for either thrust or pull of the

draw-bar, and the whole arrangement is built in the very strongest manner of steel, and each joint is strong enough vertically to carry half the entire weight of a pontoon upon it. In other words, should the entire buoyancy be removed from one pontoon for 50 ft. of its length by the trough of a wave, its weight could be rested upon the adjoining pontoon with safety.

This pipe-line has now been tested during the working season of 1903, and no breakage or failure of these joint connections has occurred, neither does the ball-and-socket arrangement show appreciable wear.

The elevator dredges which are used on the lake load into barges and can work in a moderate sea, but have to stop work when the surging of the barge against the dredge becomes too great. It was predicted that a flexible pipe-line could never be made a success in Lake St. Peter, as it would be impossible to maintain it in the waves and that more time would be lost on account of weather than is the case with the elevator dredges. As a matter of fact the position has been reversed, and with improved steel connections the dredge suffers less delays on account of the weather than the barge-loading dredges.

In order to provide flexibility of the pipe at the point of leaving the dredge a swivel elbow is employed, and the first length of pipe is short and connected to the elbow by a pair of hinges. The axis of the hinges is horizontal while that of the swivel elbow is vertical; thus the movement of the pipe is universal. The pipe leaves the dredge on the corner in order to permit the pipe to radiate from the dredge at any angle through three-fourths of a circle. The horizontal hinges at the swivel elbow will permit the main pontoons to have a vertical or wave-movement of 5 feet.

At first the discharge-pipe left the dredge through the stern near the centre of its width, it being supposed that the pipe would always drift downstream with the current, or could be anchored in that position. Such, however, proved not to be the case, as a strong wind astern would temporarily deaden the current and cause the pipe to drift upstream. The position of the point of leaving the dredge was therefore changed to that shown on the plans, with a swivel elbow which permits it to radiate at any angle through three quarters of a circle. This arrangement is entirely satisfactory. No anchorage is used at any intermediate point of the pipe. It is attached at one end to the dredge and at the other by a short cable to a scow, the entire 2,000 ft. being free to drift as it pleases. The scow is fitted with a steam winch, by which its own anchorage is controlled. It has two anchors with wire cables, 1¼ in. diam. and 2,000 ft. long. These can be hauled in and paid out as required, and this movement serves both to distribute the material, to avoid piling up above the

ıter, and also to regulate the tension of the pipe
ıs making a very wide cut. In places when the cut is
ipe tightens up to almost a straight line when the
ar side. The scow anchorage permits considerable
nent and when necessary the operator on the scow
ınchorage to relieve the tension and permit the
he cut.

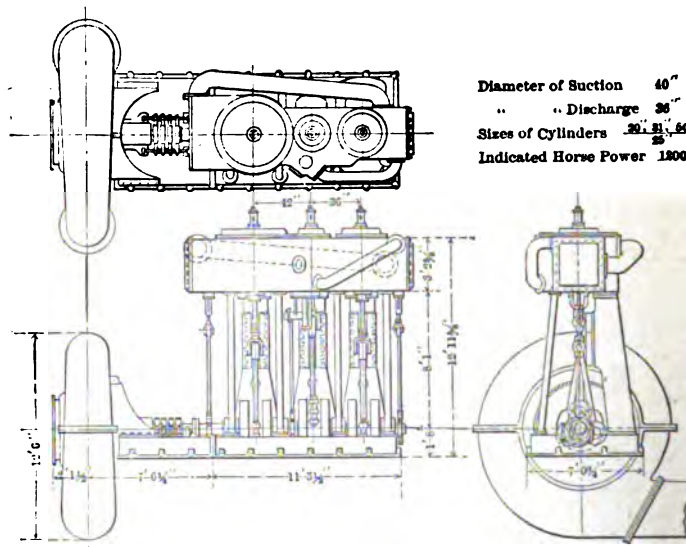
sed for holding the dredge are of large size to hold
ınchors and the bow anchor are alike as the strain
on the side anchors as on the head line. There is
ıor worked by a special winch which acts like a
that it hauls in and pays out the line automatically
verses its cut to suit the varying length and keep
ı.

o the dredge itself, the general form and arrange-
by referring to Fig. 7. The hull is of steel and is
beam, 12 ft. 6 deep. The plating is generally ½ in.
om and ⅜ in. on the sides with 5-16 in. deck. The
the bilges but is rectangular in plan with rounded
. There is a central opening, or well, through
-pipe works. This well is 8 ft. wide, except at the
re it is 10 ft. wide to admit the cutter, and it is of
o receive the pipe. The suction-pipe is formed of
l box girder of great strength, and having its lower
tended in width so as to fit between the sides of the
s of this horizontal girder are formed of two angle
. x ½ in., covered with a plate 12 in. x ¾ in., which
sides of the well. This is for the purpose of with-
t lateral strain due to feeding the dredge sideways
er in contact with the bottom. The dredge being
at a depth of 50 ft., the suction-pipe forms a lever
ıd both the hull and the attachments of the pipe
eat strength to withstand the stresses due to con-
om in a seaway and due to the lateral feeding. The
nged to the hull at the deck by means of massive
gs, and a steel bulkhead extends the entire width
s point. The sides of the hull are extended above
a solid steel bulwark entirely around the dredge,
ng formed of an 8 in. bulb angle, finished on the
ı. half round. These bulwarks form a protection
which sometimes break over the dredge.

pe is suspended from a double steel A-frame over
of the well, and the lifting winch for raising and
ion-pipe is carried on top of this frame. The sus-

pension tackle is formed of two sets of heavy wire rope tackle; the diameter of the ropes being 1⅜ in. The sheaves are of cast steel with turned grooves and brass bushings. The hauling parts of this tackle in this way pass direct to the drum of the winch without the intervention of any idler sheaves as would be the case if the winch were located below the deck. This arrangement has the further advantage of getting this winch out of the hull where it would occupy valuable space.

The main engines are of the triple expansion marine type, having cylinders 20 in., 31 in. and 50 in. diam., by 25 in. stroke. They are adapted to run at 150 revolutions per minute, with 150 lbs. of steam. The engine room is provided with a complete outfit of all the usual



MAIN ENGINES AND PUMP.

FIG 5.

accessories including air pump, feed pump, surface condenser, heater, bilge pumps, etc.

The material is excavated by an improved rotary cutter, 9 ft. 6in. diam., by 9 ft. long, the weight of which is 10 tons. It is formed of steel blades with specially designed clearance spaces between them, so as to avoid clogging with the material and the suction-pipe and passages through the pump are made very large for the same reason. The cutter is driven by a pair of engines placed on top of the suction-

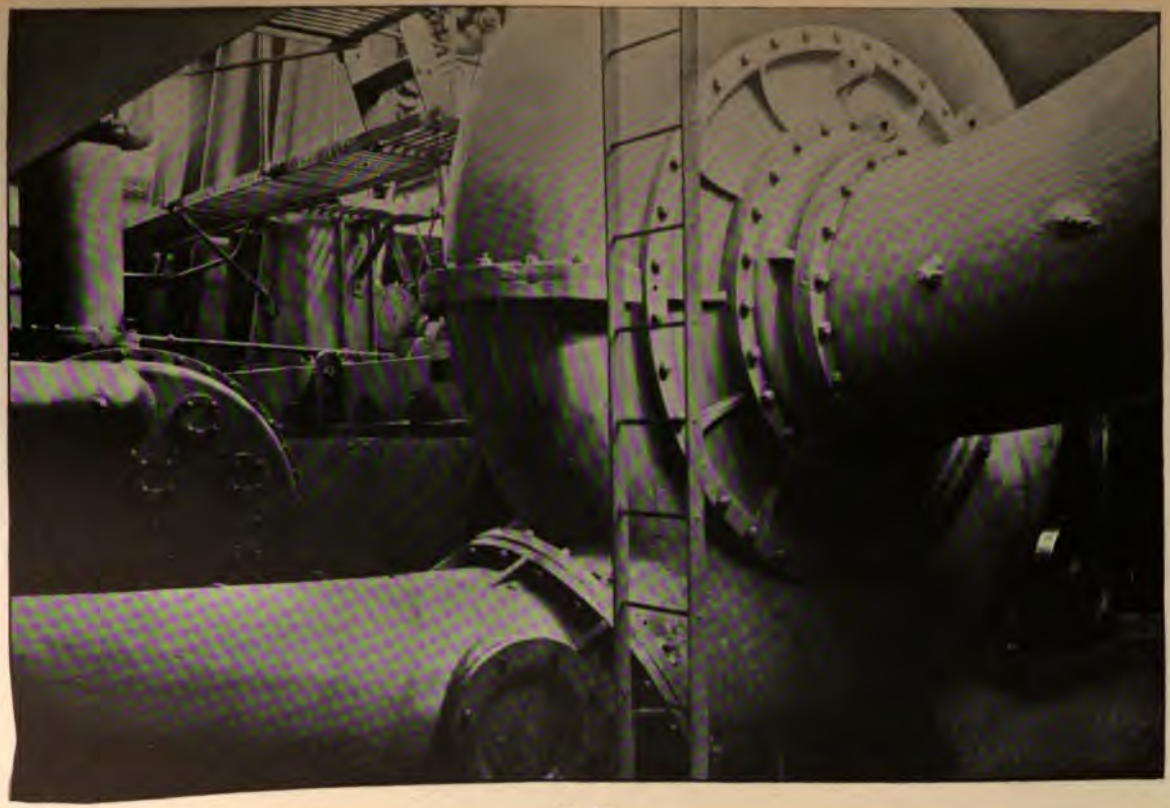


FIG. 10.
VIEW OF MAIN PUMP

pipe at the upper end. These engines are of the double tandem type of 300 I. H. P. They are of the most substantial description with all bearing surfaces extra large for continuous heavy duty. The gearing and power transmission for these engines is of exceptional strength and capable at all times of encountering immovable resistances with full head of steam on the engines without risk of breakage. The main gearing driving the cutter is of cast steel 5 in. pitch and 15 in. face. It is worthy of note that during the whole two seasons that this dredge has been in service no breakage, or failure of any kind, has occurred to any part of the suction-pipe, cutter, or cutter-driving apparatus. This is due to the exceedingly substantial character of the design and construction, and the direct manner in which the strains are met ; also to the fact that the engines are the weakest part and can be stalled at any time with safety.

Steam is furnished by four boilers, having collectively 8,500 sq. ft. of heating surface, and adapted for working pressure of 160 lbs. There is coal bunker capacity of 200 tons.

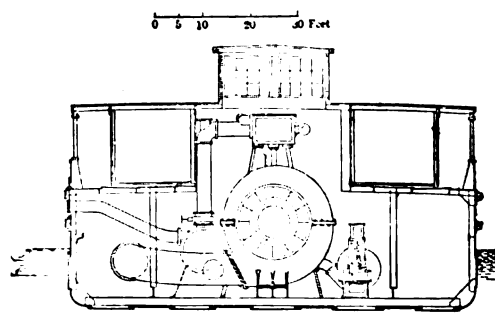
The main pump is of the centrifugal type, having cast steel runner of enclosed type and heavy cast iron shell. The blades of the runner and the heads of the pump are protected by renewable steel wearing plates in the shell. This shell is exceedingly heavy so that it can stand a considerable amount of wear before it begins to fail, and it is also so designed that the stream of material issuing from the runner does not strongly impinge upon it at any one point. In this way the tendency to wear is greatly reduced as compared with ordinary pumps. The original pump with all its parts is still in use and in good condition, after two years of service.

The whole of the operations of the dredge are controlled from the pilot-house on the upper deck. Here are located the levers for both the bow and stern anchorage winches and the lifting winch for the suction-pipe ; also a system of bells and signals to the engine room. The pilot-house is so placed that the operator has an unobstructed view up and down the river ; also of the entire discharge-pipe. It is necessary for the dredge to get out of the channel to enable vessels to pass. For this purpose the operator causes the dredge to remain on that side of the channel on which the discharge-pipe is situated and slackens out the breasting lines on the opposite side so that they rest upon the bottom.

The dredge is fitted with complete quarters for a double crew of 36 men, or 18 men on each shift. The dredge works continuously from Sunday night till Saturday night each week, without stopping, except when necessary. Several runs have been made of five or six days without a stop of the main pumping engines, the only interruption being the pause in feeding due to the passage of a ship.

The dredge is attended by a powerful light draft twin-screw tug. The principal duty of this tug is to fleet the anchors as the dredge moves ahead. The side lines of the channel to be made are marked at night by temporary range lights.

Turning now to the results accomplished, the work done during the month of June, 1902, when the dredge began work, was only 93,750 cubic yards. This was accomplished in 41¼ hours, or 14.3 per cent. of the total working time. It naturally occupied some time to get everything in good working order, to make minor improvements and to train the crew for their work, none of whom had ever operated a dredge of this type before. The output month by month steadily increased until in September, 1902, the quantity was 580,000 cubic yards; in October 600,000 cubic yards,—this notwithstanding the defects to which reference has already been made, and which were remedied during the following winter. The length of channel deepened in September was 7,800 lineal ft., 325 ft. wide by 5 ft. aver-



CROSS SECTION SHOWING PUMP

FIG. 6.

age thickness cut, and in October, 8,000 lineal ft. The dredge thus demonstrated her ability to deepen the channel to 30 ft. at the rate of a mile and a half per month.

Owing to lateness in starting in the spring and to early stoppage in the fall on account of accident to the boilers, the season of 1903 was very short, being 126 working days. During this time the work accomplished was 2,671,750 cubic yards, scow measurement, equal to an average of 21,200 cubic yards per day for the season. This includes all delays from whatever source. The best month was September, 1903, when the output reached the phenomenal figure of 757,100 cubic yards. This was accomplished in 25 days of 552 working hours, giving an average rate of 1,646 cu. yds. per hour, or 30,280 cu. yds. per day for the month. Of this time 460 hours was actual

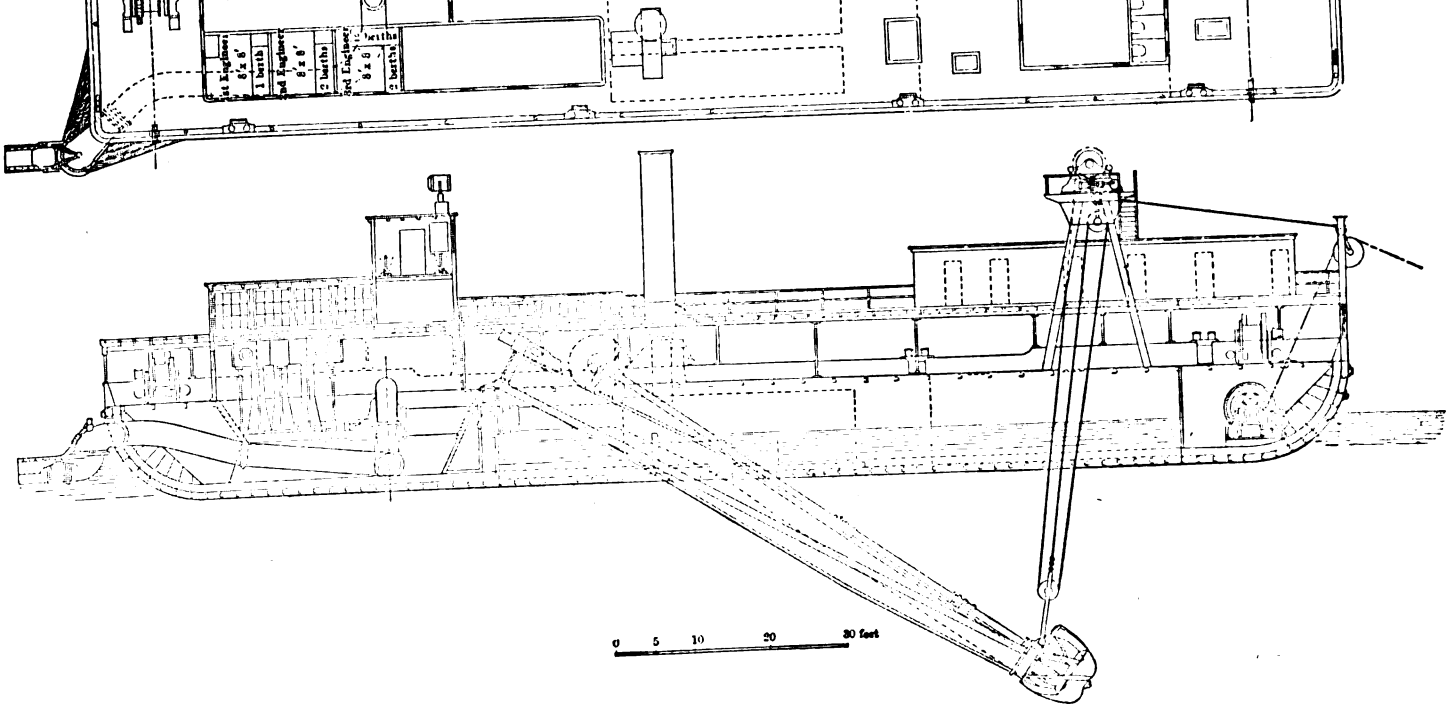


FIG. 7

GENERAL PLAN AND ELEVA

dredging, being 83¼ per cent. of the possible time. The work done was widening and deepening, at one time, the average thickness of the cut in the deepening being 4 ft., and of the widening, 14 to 17 ft. These figures show what can be done with this dredge when the working time can be kept up to a high average.

No special short time tests were made although log records show rates as high as 2,600 cubic yards per hour maintained for several hours. The average cost per cubic yard for the year is about 1⅜c.

Unfortunately, the season was cut short by explosion of one of the boilers, due to low water, and causing the loss of two lives. But for this untoward accident the work of the season would have been much greater.

The work of the month of September, 1903, is believed to be greater than that ever before accomplished in one month by any dredge. Larger outputs have been claimed for shorter periods of time and in dredging free sand from shallow depths and delivered to shorter distances. The writer believes that the only proper way to estimate the work of a dredge is to measure the results obtained by the month. A high record may be made for a single hour, or a single day, but the general results may be poor if the dredge has not the ability to maintain a high average. The work done by this dredge is determined by the engineer in charge of the river works who takes the position of the dredge in the channel at a given time, say, the first of the month. On the first of the following month he again takes the position, having also observed its progress from time to time. The quantity of material removed is then determined by the area of the cross-section of the cut made, multiplied by the advance actually accomplished during the month. In the quantities as given the volume thus determined has been increased from place measurement to scow measurement, place measurement being 80 per cent. of scow measurement. This ratio is based on actual experiment and is for the purpose of comparing the work of this dredge with the other dredges on the river, all of which work by scow measurement. As the material is blue clay, which remains in place and leaves a cleanly defined bank, the cross-section of the cut can be determined with reasonable accuracy, and in a ship-channel 18 miles long, through level flats, it is very uniform and there is no chance for any considerable errors to be made.

The table on page 18 gives a comparative statement of the results of short time tests of the "Tarte" and two of the great dredges on the Mississippi. By short time tests is meant 12 to 24 hours. Many official tests of dredges on the Mississippi were made by pumping into barges so that the volume of sand and water could be accurately measured. Much useful data was secured in this way, but as the

FIG. 8.

VIEW OF DREDGE SHOWING PIPE-LINE.

duration of such tests was only two or three minutes, the writer does not regard them as a valuable index of the working capacity of the dredge. The data given for the "Tarte" were derived from the daily log of the dredge, giving hours worked, distance covered and volume dredged. It does not therefore represent a "test" strictly so-called, but is one sample among many similar ones of what may be considered a good day's run under working conditions. The data for the "Delta" and "Epsilon" are taken from a special test recorded in Annual Reports, Chief of Engineers, U.S.A., 1899, Part V, p. 3495, for the purpose of ascertaining the performance under working conditions. These results likewise do not represent the utmost rate of which the dredges were capable, and it is recorded of the "Delta" that for a short time the capacity reached 2,550 cu. yds. per hour. The other dredges also would probably show a higher rate for a short time under the most favourable conditions.

Comparative Statement of Short Time Tests of Dredges.

"J. Israel Tarte" and Dredges of similar size on the Mississippi.

Name.	Cu. yds. per hour.	Distance Deposited.	Diam. of Discharge Pipe.	Indicated Horse Power.	Steel Hull.			Cu. yds. per H. P. per hour.	Depth of Dredging.	Kind of Material.
					Length.	Beam.	Depth.			
Delta	1,259	1,000 ft.	34 in.	1,050	175 ft	38 ft.	8ft. 4in.	1.19	16 to 18	Sand
Epsilon	1,305	1,000 ft.	32 in.	748	157 ft.	40 ft.	7ft. 9in.	1.74	16 to 18	Sand
J. Israel Tarte.	2,106	2,000 ft.	36 in.	980	160 ft.	42 ft.	12ft. 6in.	2.15	35	Soft Blue Clay

Note.—The "Delta" was tested on October 30th, 1898, and Dredged 34,560 cu. yds. in 27h. 25m.

The "Epsilon" was tested on November 26th, 1898, and Dredged 32,407 cu. yds. in 24h. 50m.

The "Tarte" was tested on October 20th, 1902, and Dredged 25,280 cu. yds. in 12h. 0m.

DISCUSSION.

The Chairman said he thought the Society was to be congratulated on producing such a paper. He thought every one would admit that a great many of the details described showed a considerable amount of ingenuity and skill. He had been particularly struck by the details of the pipe line and many other details. He said that he had seen the dredge working, and was very much impressed with its operation. From a commercial standpoint, it was probably the most important machine we had in the country. Mr. Blackwell.

Mr. H. A. Bayfield stated that one question he would like to ask the author was in connection with the pipe line. He had noticed that the sections of the pipe line were joined together by rubber sleeves, and it seemed to him that the life of the rubber sleeves would be short, owing to the very severe usage to which they must be subjected. Was this the case? Also, by what means were the sleeves secured to the pipes? Mr. Bayfield.

Mr. A. W. Robinson said that the rubber sleeve formed a flexible connection between the pipes and was not fastened to the pipe except by bands clamped on. The sleeve was very substantial and the very best quality of rubber was used. A great many experiments had been made to find a substitute for the rubber sleeve but nothing had been found to answer so well. The present sleeves had been used throughout two seasons' work, and had been found to stand the service fairly well, being still in condition for use. Mr. Robinson.

Mr. K. W. Blackwell said that he would like to ask a question in regard to lost time. Was the time lost, owing to the dredge having to be moved to accommodate passing boats, a serious item? Mr. Blackwell.

Mr. Robinson answered that often it was serious, and when the large amounts of work stated in the paper had been accomplished in spite of these delays, they should be taken into consideration. There were sometimes eight or ten ships passing in a day, and if it so happened that the dredge could remain at the right side of the channel, not more than ten or fifteen minutes would be lost. Otherwise, sometimes more than half an hour was lost.

Mr. Bayfield asked what would happen if a boulder would get into the pump? Could it get in, or were the cutters arranged in such a way that anything they took in would go through the pump and pipe line? Mr. Bayfield.

Mr. Robinson, in reply, said that in Lake St. Peter there were comparatively few boulders. For the greater part of the work there were no boulders at all, and it was perfectly smooth clay. Mr. Robinson.

Mr. Robinson. In some places there were quite a number of stones, but the passages through the pump were very large so that everything that could enter the suction pipe, would go through it. They never had such a thing occur as a stone sticking in the pump or pipe line. Where stone deposits occurred the noise of the stones rattling through the pipe could be heard at a distance of two or three miles on a still day.

Mr. Kerry. Mr. J. G. G. Kerry remarked that in regard to Mr. Robinson's mention of the Mississippi River, he had had the pleasure some years ago of hearing Mr. Randolph give a lecture in regard to the Mississippi dredges, and at that time the problem of keeping the Mississippi open during water season had been solved by the invention of this type of dredge. Mr. Kerry said that he also noticed some reference in Mr. Robinson's paper to the changing in the water plane of the river, and he would be glad to hear his opinion on that.

Mr. Robinson. Mr. Robinson, in referring to the results obtained in dredging the Mississippi River, said that the results showed that navigation had been distinctly improved, and they had obtained what they wanted, namely navigation of six to nine feet, at low water; and this had been accomplished with a comparatively small amount of dredging. It had been found that when an opening was made through a sand-bar, by careful working in connection with the current, the erosion or scour might assist in the maintenance of a channel. It then became comparatively permanent, or as permanent as anything could be on the Mississippi—so much so that they were able to find some evidences of it the following season. With regard to the changes in the plane of the river, Mr. Robinson stated that he did not attempt to touch upon that at all. The change in the datum was due to the fact that a new low water datum had been established, because in extremely dry seasons, the water went below the existing datum.

as held Thursday, March 24, 1904, Mr. R. A. Ross, of the Section, in the chair. The subject of the The Use of Electricity on Canals." It was illus- ollowing papers:—

OF ELECTRICITY ON THE LACHINE CANAL.

L. A. HERDT, A. M. Can. Soc. C. E.

Canal is part of the large waterway which connects with the Gulf of St. Lawrence. This waterway, com- hty St. Lawrence River and the chain of lakes of the is, as regards the beauty of its shores, the grandeur nd the majesty of its falls, without any rival. But inland water route, it is unsurpassed in the world ial usefulness.

al length of 2,400 miles, 1,000 miles from the Atlan- ontreal, the metropolis of Canada, and 1,400 miles to ke Superior, it allows free and safe navigation to to fourteen feet draught.

rence River, the canals and the great lakes, have be- artery of commerce, serving to carry the freight of nada to Europe, besides supplying the local traffic of s and villages lying along their shores.

es for navigation, however, were not obtained with- e outlay of money, of time and of labor, and without rks of the highest order. Among such works are to e magnificent system of canals, comprising the arnois, Cornwall, Soulanges and Welland canals. length of these canals is 70¾ miles, with a total ½ feet, through 54 locks.

THE LACHINE CANAL.

1903 the Lachine Canal was opened to navigation 246 is time 7,365 vessels of all description passed through r two million of tons of freight and 35,000 passengers. of wheat, 218,000 tons of corn, 22,000 tons of flour,

327,000 tons of lumber, 370,000 tons of coal and half a million of tons of general cargo passed through its locks.

A few words as to the history of the construction of the Lachine Canal will not be out of place, especially as a complete history is yet to be published.

Immediately above Montreal are found the rapids of Sault St. Louis, or Lachine Rapids, which are the first obstruction to westward navigation in the St. Lawrence River. To continue the water route, as far back as 1700 the Sulpician Fathers opened up a boat canal, merely a trench, via River St. Pierre in the marshes where the Lachine Canal at present lies. The depth of water was but two and a half feet, and served for boats to carry thirty barrels of flour. The locks were six feet wide and one hundred feet long.

This was enlarged and deepened in 1821 to allow for navigation by barges drawing four feet. The locks were lengthened to one hundred and fifty feet and broadened to twenty feet.

In 1843 a ship canal was begun at a cost of two million of dollars. Five locks were built, each 2,000 feet long and nine feet of water on the sills.

The length of the Lachine Canal is eight and three quarter miles. From Lachine to Côte St. Paul, a distance of five and three-quarter miles, there are no locks, the Lachine locks being, in fact, only guard locks, the lockage is but a foot.

From Côte St. Paul to Montreal harbor, a distance of three miles, the total lockage is forty-five feet.

The Canal is spanned by six swing bridges built on piers of cut stone. These bridges are the Lachine bridges, Côte St. Paul bridge, Brewster's bridge, the Grand Trunk, Curran and Black's bridges. The last three are very heavy.

Use of the Electric Power—

In 1902 the Department of Railways and Canals decided to take advantage of the available water power on the Lachine Canal to generate electric current for the following purposes :—

1st. To light the canal, the locks and approaches of the bridges.

2nd. To electrically heat the power house and lock cabins.

3rd. To open and close the lock gates, sluice valves and waste weirs.

4th. To operate the bridges spanning the canal.

To provide for these different services it was decided to provide the following equipment :—

For the lighting, 100 arc lamps, placed along the canal bank and at the locks, and approximately 100 16 c.p. incandescent lamps for lighting the power house and lock cabins.

Fig. 1.

For heating, six 6-kilowatts electric radiators, in the power house, besides a number of small heaters in the lock cabins

For the operation of the locks, twenty-four 5 H.P. Induction motors; for the bridges, four 5 H.P. motors.

The maximum station load due to these different services is far from their aggregate sum, as the different services are not required at the same time, and as all the motors cannot operate together. For instance, it would rarely happen that all the lock gates would operate together, and further with the arrangement of machinery described below, only half the motors, that is two motors out of the four, per lock, can be working at the same time.

The full capacity of the radiators would be required only in the winter months, at such time the canal is closed to navigation, the motors are not in operation and the lighting is limited to a dozen lamps which are required for the approaches to the bridges.

Proceeding from the assumption that all the purposes for which electric power is provided cannot take place at the same time, the size of the generator units was based on the following :—

100 Arc Lamps, four circuits of 25 lamps, 6.6 amps. per circuit, at 2,400 volts..	63.5 K.V.A.
Four locks out of the six in operation together, that is 8 motors developing 4 H.P. each. Assuming the efficiency of motors, transformers and line at 70% and power factor 80%..	42.5 K.V.A.
Two bridges out of the four in operation together, that is 2 motors developing 4 H.P. each, assuming same efficiency and power factor as above..	10.5 K.V.A.
Heating of power house and lock cabins average..	24 K.V.A.
A total of..	140.5 K.V.A.

Two 75 K.V.A. generator units were considered amply sufficient to take care of this maximum load. During the day there would be no lighting, one generator could carry the power and heating load. At night the operation of both machines might be required but for a few hours, the night traffic being usually small.

Hydro-electric Plant—

The power house is located at Côte St. Paul, on the south side of the canal. The working head of water is about eight feet. The water is drawn from the canal through a wooden flume 15 feet by 11 feet, built in the Côte St. Paul overflow weir. Fig. 1 shows an exterior view of the power house, flume and overflow weir under construction. The power house is a fine building of pressed bricks,

above a line of cut stone and concrete arches. Fig. 2 shows a back view of the power house, tail race and foundations.

Two 75 kilowatts, revolving field type A.C. 3-phase 2,400 volt, 60 cycle generators are belted to 7'-8" fly wheels. The latter are placed on two horizontal shafts geared to the vertical shafts of 125 H.P. turbines.

The two horizontal driving shafts are in line so that they can be connected by a quill, allowing either generator to be driven by either one of the turbines. Fig. 3 shows the arrangement of machinery on the generator floor.

One 7.5 kilowatt exciter is operated from a separate water wheel. It is of sufficient capacity to excite both generators when working under full load and 75% power factor. A spare exciter armature is kept in reserve.

Switchboard—

The switchboard is of the ordinary panel board form, comprising two generator panels, one exciter panel and one feeder panel. This switchboard is placed on a gallery, eight feet above the generator floor.

The generator panels comprise the necessary indicating ammeters, voltmeters and wattmeters. Oil type switches are used. A power factor indicator and frequency meter are placed in the circuit of each generator.

The exciter panel has a D.C. voltmeter and two ammeters, one in the field of each generator, also carbon quick break knife switches for the generator fields.

The feeder panel has an ammeter and high tension oil switch in each circuit.

The lighting of the switchboards and power house is done from a small transformer in the generator circuits, but it can be thrown on the exciter circuit if required.

Arc Switchboard—

An arc switchboard is located to the left, on the second floor. Access to this board is obtained from the switchboard gallery. Four constant current transformers used for the arc lighting are placed still further to the left, inside a square brick tower, three stories in height. The four arc light circuits of 25 lamps each are controlled by tubular plug switches which can be so connected that any arc lamp circuit can be connected to any one of the four transformers.

On the right of the main switchboard, on the second floor, is placed a board to control three 15 K.W. constant potential transformers for the electric radiators heating the building.

Fig. 2.

The cables from the switchboard are placed in conduits and run up against the walls of the brick tower to the top story, which is devoted to the lightning arresters and the distribution of the ends of the cables to the arms which support the transmission lines.

Lighting of Canal—

One hundred arc lamps, as stated previously, are distributed along the canal and at the locks for lighting. The lamps are spaced four hundred feet along the canal bank, that is a lamp on every fourth pole, these being one hundred feet apart. At bends, the

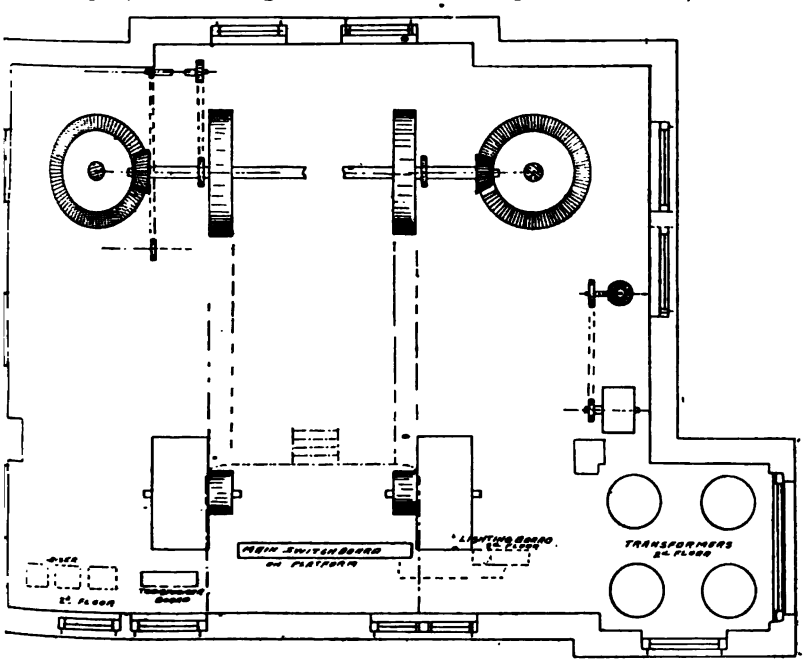


Fig. 3.

lamps are spaced to give proper illumination. Eight lamps per lock are used, giving a decidedly brilliant illumination, and securing as safe navigation at night as in the day time.

The series alternating current 6.6 ampere enclosed arc lamp is used, the regulating device being the floating coil automatic constant current transformer.

The lamps are hung twenty-two feet above the ground, from brackets. The lamps can be carboned from the ground, as a small hand reel attached to the pole eight feet from the ground allows the lamp to be brought down, through a flexible steel rope running through the tubular arc lamp bracket. This avoids spiking the poles which in lines running in open country is undesirable.

Pole Line Construction—

The pole line construction is substantial and somewhat artistic, the ornamental braces and brackets used giving it this appearance.

Cedar poles painted white are placed one hundred feet apart, and six feet from the water edge, to clear the space for the tow path. Two six pin arms are used throughout, and double arms are placed on all turns, these arms are bolted through the poles and at the ends.

On the side of the poles further away from the canal is carried the three phase 2,400 volt power circuit. One circuit runs west of the power house to the Lachine locks, a distance of nearly six miles. It is made up of three No. 4 B. & S. medium drawn bare copper wires. The wires are placed in triangular form 18" from wire to wire. A circuit running east to St. Gabriel locks, a distance of two miles, is made up of three No. 6 B. & S. wires.

On the side of the poles nearest to the canal are placed the arc light circuits. Three of these, each of two No. 6 B. & S. bare copper wires, run west of the power house, each circuit connecting twenty-five arc lamps in series. One arc light circuit runs east for the remaining twenty-five arc lamps.

The high potential lines for lighting and the 220 volt power circuits cross the canal at each lock in rubber insulated lead covered cables. These cables start from cable boxes placed on the poles, and run down the poles in iron conduit to manholes, and hence under the locks in pipe conduits. Fig. 5 shows construction of cable crossings.

The cables can be drawn in or out at any time without delay. Spare conduits and cables are in readiness to change over if any cable shows signs of break down. The cables boxes on the poles also contain lightning arresters.

Electric Heating of Power House and Lock Cabins—

Six electric radiators each of six kilowatts capacity operating under 220 volts are placed in the power house. These radiators have been in operation during the past winter and have been found sufficient to keep the power house very comfortable even in the coldest nights that have been experienced. As the load in winter is very

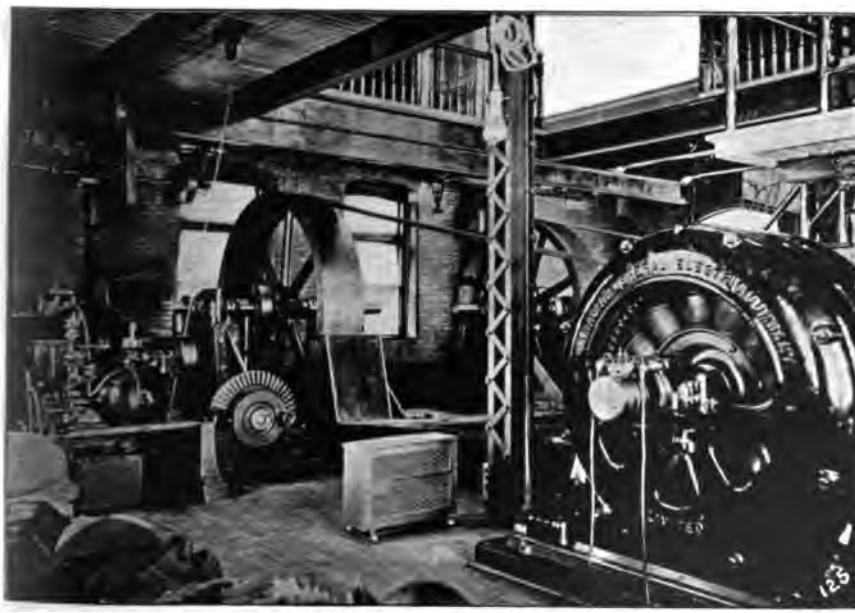


Fig 4.
The Interior of Power House.

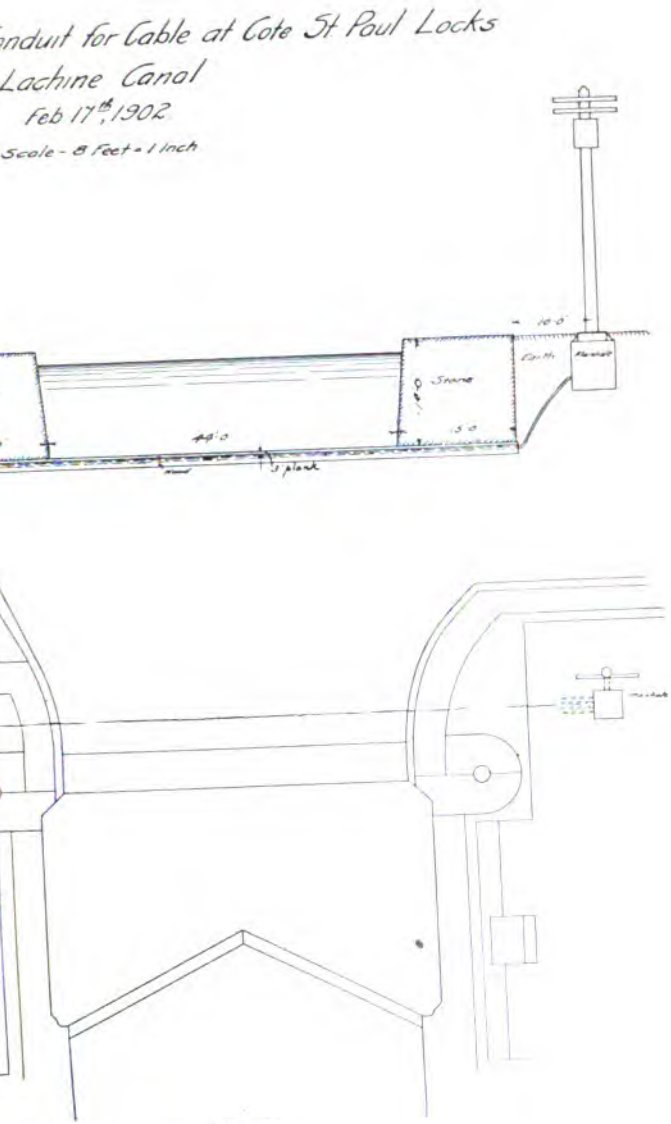

nduit for Cable at Cote St Paul Locks
Lachine Canal
Feb 17th, 1902
Scale - 8 Feet = 1 Inch
Stone
44'0
3 plank

Fig. 5.

light, the 36 kilowatts required for heating necessitate the running of only one generator.

Three 15 kilowatts transformers, one on each leg of the three phase, 2,400 volt circuit, are placed in the power house, stepping down to 220 volts, for the radiators. A switchboard with high and low tension switches, is provided for this work.

Mechanism for Operating Lock Gates and Sluice Valves—

The old system of operating the lock gates and sluice valves by man power, does not require very long description. On the Lachine canal, four winches per lock are placed on the coping. By means of these winches, chains which open and close the gates are operated. This system is slow, over a minute and a half being required to open or close a gate ; it is also expensive as it requires, to perform the work at that rate, at least two men per winch or four men per lock. The sluice valves for filling or emptying the locks are on the gates and are operated from the gate platform, through gearing, lifting vertical rods or stems attached to the valves.

Electric Power Driving—

In changing from the above method of operation to one employing electric power, the following conditions were to be fulfilled :—

1st. The coping on both sides of the gates, and the gate platform had, as far as possible, to be free of machinery.

2nd. One electric motor had to operate one gate, opening and closing, also raising and lowering the sluice valves on this gate.

3rd. A mechanism of such simplicity had to be employed, as would avoid skilled labor.

4th. Operating staff had to be reduced to one man per gate, that is two men per lock.

In order to meet these conditions, the method to be described was devised by Mr. Marceau, superintendent engineer, Mr. Parizeau of the engineer's staff, and the writer, and was adopted. It might be stated in passing that a number of other methods could have been used, to do the same work, which, however, would not, we think, meet the specified condition in the same complete manner.

The whole of the driving machinery for operating one gate and its sluice valves, is placed on the gate, under the gate platform. (Fig. 6.) The space there is rather limited, still it is found to be sufficient for the purpose. Power is supplied by a 5 H.P. three phase 220 volt induction motor running at 1,120 R.P.M. This motor is shown on the right hand of Fig. 6. This motor is geared to a horizontal shaft, running approximately two-thirds the way along the gate. The speed of this shaft is 300 R.P.M. A reversing switch

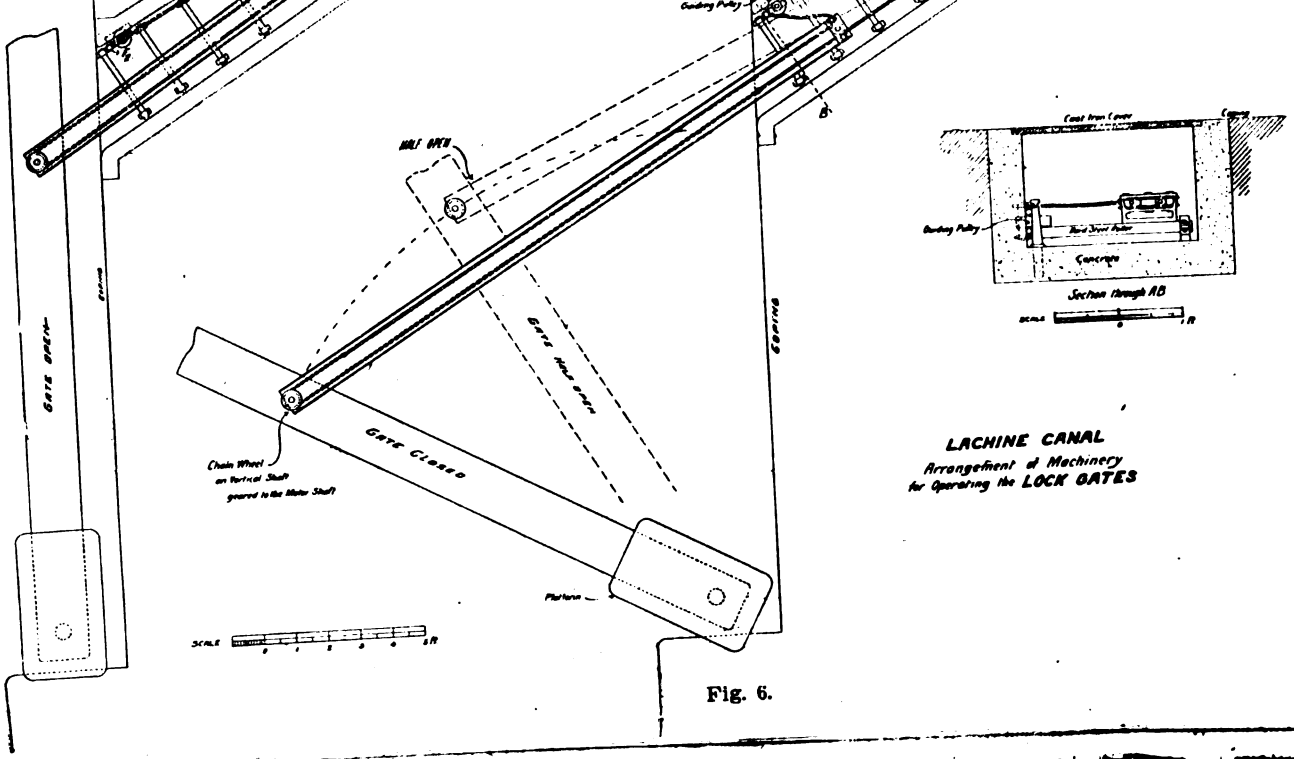

Guiding Pulley
HALF OPEN
GATE OPEN
GATE HALF OPEN
GATE CLOSED
Chain Wheel
on Vertical Shaft
geared to the Motor Shaft
Platform
SCALE
Cast Iron Cover
Guiding Pulley
Concrete
Section through AB
LACHINE CANAL
Arrangement of Machinery
for Operating the LOCK GATES

Fig. 6.

and starter, controlling the motor, is placed close to the handles of the clutches, which operate the machinery. Three worm gears A, B and C are placed on this shaft ; A and B to operate the two sluice valves, C to operate the lock gate.

Mechanism for Operating Sluice Valves—

Gears A and B are loose on the shaft, but can be thrown in gear through friction clutches, and engage brass horizontal worm wheels, which in turning, lift threaded stems or rods attached to the valves. The opening of the valves requires barely half a minute. A supplementary gearing enables the operator standing on the gate platform, to open or close the gate valves by hand if the electric power fails.

Tests made on an experimental outfit, last spring, to ascertain the power required to open and close the valves gave the following results :—

Motor running shafting only..	1,050 watts = 1.4 H.P.
Opening sluices..	1,500 watts = 2.0 H.P.

Time required to open valve = 30 seconds.

Mechanism for Operating the Lock Gates—

A steel worm gear C, running in oil is keyed to the horizontal driving shaft, and engages a horizontal brass worm wheel. This wheel rotates freely on a vertical shaft, which is the pivot for a U steel beam, resting on the gate on one side, and working in a cut provided in the coping at its outer end.

A friction clutch operated from the gate platform throws this wheel in gear with the vertical shaft, driving it at a speed of 15 R.P.M. A square brass casting, bored to fit this shaft and through which the latter passes, is placed in the web of the beam and holds it in place, allowing a certain amount of play whilst the gate is being moved. A chain wheel is keyed to the vertical shaft imparting motion to a chain and steel rope.

Drawing Fig. 7 shows three positions of beam with, 1st: gate open, 2nd : gate half opened ; 3rd : gate closed. The chain and rope after passing over the chain wheel run inside the web of the U beam, to guiding grooved rope wheels, placed at the outer end of the beam. The end of the rope is attached to two points in the cut made in the coping. One point F_1 is in line with the beam and at the inner end of the cut, the other point F_2 is near the edge of the coping. The beam is allowed to rest on hard steel rollers, placed on a bed of concrete slightly sloping towards the lock to carry away the surface water. An iron grating is fitted over this cut and allows inspection of the machinery at any time.

Opening the Lock Gate—

To open the lock gate, the motor is started under no load except the friction of the shaft, in the direction indicated for opening. When up to speed, the friction clutch is operated, allowing a certain amount of slipping at the start to avoid sudden strains on the machinery. The chain wheel running clockwise will pull, through the chain and rope, on the point F_1, drawing in the beam towards the coping. The pivoting point P will describe the dotted circle shown. The outer end of the beam is guided by the rope in tension passing through the grooved pulleys until it reaches its position of rest at the end of its course. The gate is then open.

Closing the Lock Gate—

To close the gate, the direction of rotation of the motor is reversed, and thereby the rotation of the chain pulley, the rope tension is now on the point F_2, the beam will swing slightly as the rope becomes taut, until the beams rest on the guiding pulley shown on the left in the inner portion of the cut. The beam will then move out with the gate until the latter is closed.

It must be observed that in both the opening of the gate and the closing of it, the maximum pull is required at the start, and that this pull is directly along the axis of the beam whilst opening, and at a very small angle to it, when closing, thus bending moments and abnormal frictional resistances are avoided.

The induction motor being up to speed when the clutch is thrown in, is able to develop its maximum torque. With the present reduction in gearing the pull on the chain is approximately 1,200 lbs.

With an average speed of chain of 28 feet a minute, the opening or closing of a gate will be done inside of a minute. Greater or lower speeds of operation can be obtained by a change of diameter of chain wheel.

Two operators will be required, standing respectively on the platforms of the gates. Through the friction clutches they will be in position to speed up or slow down, to allow the gates to come in well together.

Tests made with an experimental apparatus slightly different from the one described gave the following readings :—

Motor running shaft alone..	1,050 watts..	1.4 H.P.
Starting to open gate..	3,200 watts..	4.42 H.P.
Opening gate, 10 sec. from start.. ..	2,500 watts..	3.3 H.P.
Closing gate at start, heavy wind blowing against gate..	4,200 watts..	5.6 H.P.

The induction motors are 220 volt three phase moters. To stop down the 2,400 volt of the transmission lines, three 5 K.W. transformers are placed on a pole at each lock. Lead covered cables run down the poles in iron pipes and then underground to the masonry walls of the locks to the gates at the pivoting point.

Only the lower voltage will be distributed about the locks.

HAND WHEEL
FOR OPENING VALVE

AL EQUIPMENT FOR CORNWALL CANAL.

By F. H. Leonard, Jr.

equipment for the Cornwall Canal is supplied with
power house of Mr. M. P. Davis, near Mille Roches,
Canal. Messrs. T. Pringle & Son were the engin-
ctrical equipment was installed under the personal
e writer.

y described the hydraulic and generating equipment
the "Canadian Engineer" and in the "Electrical
neer," but to obtain a comprehensive grasp of the
ve will again recite some of the particular features
h it.

situated just below the lower dam on the Cornwall
Village of Mille Roches, and takes water from the
h is an artificial lake made by the construction of a
ormer river bed. The tail water empties into the
ich was left dry—except at certain seasons of high
onstruction of this dam. There is obtained by this
nder ordinary circumstances, of about thirty feet,
f high back water the plant was designed for opera-
on a minimum head of eighteen feet.

s short and cut at about right angles to the weir
outh end of the dam built to take care of the over-
per level.

ks and stop log checks are built in one frame of
n front of the entrance to the concrete wheel cham-
e stop logs, head gates are provided opening in two
of worm geared head gates winches. Two large
he centre of each pair of wheels provide for access
mbers and are large enough to pass the runners
of repairs.

ouse partly covers the wheel chambers, the concrete
akes a portion of the switch board gallery which is
centre by a platform extending three feet beyond the
head wall.

use foundation rests on the solid rock, the wheel pit
to a depth of about ten feet below the surface of the

bed rock. The arches over the wheel pit are of concrete but faced on the outside with rough picked masonry of large dimensions, which gives to the entire structure a very substantial appearance. The power house is constructed on a steel frame having brick walls and heavy plank roof.

A hand power crane of twenty-five ton capacity with two trolleys having a span of thirty-eight feet is provided for erecting and handling the machinery. (See photo on next page.)

Provision was made for four hydraulic units, giving an ultimate capacity of approximately 6,000 H.P. Each unit consists of 5-35" New Sampson wheels by Wm. Hamilton & Co., with horizontal shafts directly coupled to a 1,000 K.W. Bullock Generator operating at 2,200 V at 180 R.P.M. and 60 cycles.

The switchboard gallery is about nineteen feet above the main floor of the power house and accessible by means of a flight of iron steps in the centre and two iron ladders at either end of the power house.

At present but one unit is installed with 2-50 KW. exciters 285 R.P.M. Switchboard panels are provided for the control of the generators, exciters and the various feeders.

The arc lights, of which 225 are located along the bank of the canal, were furnished by the G. I. Co., of New York. A three panel switchboard controls the operation of these lamps and each circuit is regulated by a 100 light G. I. regulator capable of maintaining practically constant current with any number of lamps in circuit from 1 to 100—its full capacity.

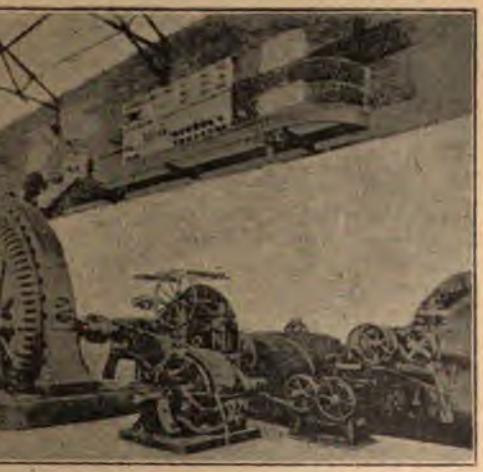
The current for these circuits is stepped up from 2,200 V. by means of transformers of 60 K.W. each—the transformers being provided with intermediate taps so that besides the full voltage of 11,000 V., if a smaller number of lamps are required, either 4,400 or 6,600 V., can be used, thus reducing the re-actance necessary to maintain a proper voltage and permitting of a higher P.F. under the conditions of partial load.

Current for the power circuits, three in number, is obtained by stepping up from the generating voltage to 11,000 V. by means of 3 150 KW. transformers which supply the 3 P. transmission lines reaching various locks along the eleven miles of canal.

The primaries of both arc lighting and power transformers are controlled by oil switches connected to the bus bars on the main switchboard, a separate panel being provided for each class of service. The power circuits are passed through a separate high potential switchboard which connects the transformers to the three separate 3-phase power lines. A 2,200 V. line also provides Mille Roches with light and power service.

esters and choke coils are provided for the various
iring of the station between generator and switch-
e tower, from which the circuits are fanned out to
es, is all carried in three conductor cables lead
trenches being provided in the concrete floors
ace for additional cables.

for the lighting and power circuits are of substan-
exceedingly straight lot of cedar poles being used.
30 to 50 ft. in height, none having less than 7"
ch were boiled in stearic acid, 5½ 11 (inch) triple
sulators being used with satisfactory results with
uits. Bare copper conductor is used spaced 16" on
ccount of the low current per line no attempt was
triangular arrangement of conductors, the three



cuit being arranged side by side without transpo-

ower circuits occupy the upper arms and on the
ocated the single phase arc circuits. The main
outh bank of the canal.

nade at the Mille Roches bridge in armoured paper
ree phase 2,200 V. power and lighting circuits and
ingle phase 11,000 V. arc circuit. Another crossing
, which provides for 3-phase power circuit, as well
V. arc circuit to provide for power and lighting on
elow this point.

At the Stormont Bridge, near Cornwall, another 11,000 V. arc cable provides for lighting the two piers at the bridge and an emergency cable is laid just above lock 17 so that in case of accident to any of the other crossings or a break in the line, emergency connection can be made in the houses covering the cable heads on the bank of the canal.

While in some cases, sawed octagon poles have been used for a similar purpose, yet the shaved cedar poles selected in this case, present an exceptionally pleasing appearance. Extreme care has been taken in locating and setting out the line and a transit has been used for the work, making the alignment and location almost perfect.

The line is well guyed on the curves with galvanized signal strand well anchored, or, in some cases, tied to a heavy guy stub. On the sharp curves, poles are double armed to provide for the severe strain.

LIGHTING.

The lighting of the canal is carried out in a very liberal manner, an arc lamp being located on every fourth pole and the poles averaging about one hundred feet apart. At the locks, as many as twelve or fourteen lamps are located so as to brilliantly illuminate both ends of the locks, as well as the intervening space and the regulating weirs—most of which are located beside the locks.

The lamps are hung from iron pipe brackets which pass through the pole and are held in place by a collar at the front side and a lock nut at the back and braced on the under side by an iron pipe strut fastened to the face of the pole by two lag screws. An insulated hanger is used at the outer end of the bracket (2′-6″ from the pole) which, together with the insulators on the lamps, renders danger from grounding in the lamp frame and bracket extremely remote. The lamps are trimmed from the pole without lowering; pole steps are driven in each lamp pole.

Loops are cut in from transposition insulators by means of No. 8 flexible rubber covered conductor soldered to the bare copper line conductors, particular care being taken to support the connection at the lamp so as to avoid any possible danger of the swing of the lamp causing a break at the binding post. Some trouble of this character was at first experienced but was soon overcome by the above provision.

At the lower end of the canal, where three sets of locks are grouped together, the illumination is very brilliant, and viewed from the Stormont Bridge at Cornwall—taking in at a single glance some sixty arc lamps reflected in the still waters of the canal—the sight is most impressive in its quiet brilliancy.

A description of the illumination of one of the locks will convey a very clear idea of them all.

A light is located at the piers as the lock is approached from below, and an arc lamp is also located at each side of the lock just below the gate ; two more lamps are located at the middle of each lock and two at the upper end of the lock just at the lock gates. There are also two more at the upper piers and as two locks are located side by side, it is easy to imagine that the illumination would almost rival day light.

Below lock 18 both banks are illuminated all the way by lamps located 400 ft. apart. Above lock 18 the lamps are located on the south side of the canal only, with the exception of prominent points, bridges, etc., where lamps are provided on both sides.

The upper level broadens into a lake of considerable proportions, about thirty feet deep near the lower end the dam retains the water between Sheik's Island and the Canadian shore, making a broad and easily navigable waterway of about three miles to the upper dam. The lamps are here less frequently located on the prominent points on the south side until the upper dam is reached when the canal again narrows to the usual dimensions.

The lamps are again located about four hundred feet apart on the south bank up to lock 21, which is a guard lock, there being very little difference between the upper canal level and the St. Lawrence River at this point. On the long pier on the south side protecting the canal entrance lamps are placed, as well as on the north bank as far up as Dickinson's Landing.

An illumination so perfect as above described, makes navigation as easy at night as in day light and lockages are performed as rapidly and as easily as they could be in the day time.

LOCK HOUSES.

At the upper end of each lock on the south bank there is located a small switchboard cabin, 7′-0″ x 9′-0″ ; on the little island between the two locks is located another switchboard cabin and at the upper end of the lock on the north side of the second lock is another cabin.

In the first of those above mentioned are placed three transformers connecting to the 11,000 V. mains, which step the voltage from the line pressure to 550 V., and it is at this pressure that the motors operate. A high tension fuse board is provided to take care of the primary connections to the transformers. The long enclosed fuse has friction contacts at either end and by pulling these fuses out of the end clips by means of a wooden stick with a hook at the end, the circuit can be opened in case of temporary trouble, or for any purpose when it becomes necessary to disconnect the transformers.

The secondary of the transformers passes through the switch on the switchboards which distributes the secondary current to the motors, two of which are located on each side of the lock. Armoured cable with paper insulation is used to conduct the current from the switch cabin to the motors located on the same side of the lock.

The connection for motors on the opposite side is carried through armoured cable which leads down through the floor of the switch cabin and passes through a hole drilled in the stone coping of the lock to the upper stop log check—there being two checks cut in the masonry. This leaves one which could be utilized for stop logs in case it ever became necessary to keep the water out of the lock during repairs. The cable turns over a radius of 16″ at the top and passes down the check, being protected by a piece of oak plank which is grooved in the centre to take the cable, the plank being fastened by drift bolts to the stone work and protected at the edges with iron strips. As the plank does not come above the edges of the check in the stone work, there is practically no danger of the cables ever being injured by a boat in entering or leaving the locks.

Where the cable crosses on the lock bottom a timber is held on top grooved on the bottom side to receive the cable, and as the top of this timber is well below the breast wall at the entrance of the lock, there is no danger of the cable ever being disturbed.

Rising on the opposite side of the lock in the stop log check, the cable again passes through a hole drilled in the stone coping until it comes out of the earth back of the masonry under the next switch cabin, from this switch cabin the cable is carried into the third switch cabin on the north side of the old locks.

You will bear in mind that the new locks were built on the south side of the old locks, and are about 70 feet longer, the old locks being 55 feet wide and 200 feet long inside the gates and the new locks 45 feet wide and 270 feet long inside the gates and 14 feet over sills.

On the switchboards in each of the cabins are placed the motor starting switches connected to auto starters which control the motors on one side of each lock. From the switch cabin on the south side are operated two motors, the first motor being connected by armoured cable reaching from the switch cabin underground to the first motor. The second motor is reached by conductors running from the switch cabin overhead to a pole very near the motor at the lower end of the lock, armoured cable connecting from the pole underground as far as the masonry and checked into the masonry where it passes over to the motor.

The switch cabin on the little island between the two locks controls the two motors on the north side of the new locks and two motors on the south side of the old locks. The third switch cabin

rs on the north side of the old locks, as well as the
the weir gate mechanism.
ent is identical in all the locks with the exception
lock 16, which are not provided with weir gates.
t for operating the lock gates and weirs was adapt-
nnection with the winches and weir gate mechanism
without disturbing their capability for hand oper-
sion require.
evices were operated by hand, the lockmen labor-
ank on the winches at the two opposite sides of the
ng one winch for opening and the other for closing
winches were located at each end of the lock, two
of which handled the chain to close the opposite
open the gate on the side at which these winches

of each gate is a bridge on which is mounted the
for opening the two valves in each of the gates
fill or empty the lock.
equipment utilized practically all of this machin-
th only the necessary changes to make the mechan-
with the electrical drive.
ep the speed down to approximately what was ob-
peration, a very material reduction in motor speeds
To obtain this and cover the other points, special
evised and patented by Mr. Alex. Pringle and the
shown in the drawing attached.
lected were all of 5 H.P. for both the lock gates
ism. Some question as to whether a 3 or 5 H.P.
adopted arose, but the matter was decided in favour
otor on acocunt of its lower speed; and while the
motor is never exceeded except for a few seconds,
e time running considerably under load, yet the
nt is simple, and while somewhat stronger than
ed, the interchangeability and greater durability,
ustified the slight additional expense.
two winding winches which control the chains for
ng the gates, one motor is located near the hollow
f the lock gate, which is coupled by means of short
and friction clutch coupling to the winch near this
ans of another friction clutch and length of shaft
the other winch, supported at intermediate points
ying journal boxes mounted on cut stone blocks

jointed to the coping, making a practically continuous stone foundation for the mechanism.

The arrangement of the motor bed, gearing and speed reduction will be more clearly understood by referring to the drawing showing the casing for the worm gear and motor bed.

As there is a reduction of about 42 to 1, which gives a speed of about 26 revolutions for the operating shaft, it was decided to use the worm gear rather than a more complicated triple reduction by means of spur gears. A sub-base extends under the motor and also carries the casing for the worm and worm gear. The worm runs in oil, the thrust being taken up by alternate steel and bronze collars and thrust discs, adjustable at one end by means of set screws and check nut to compensate for wear.

The motor, which runs at 1,200 R.P.M., is coupled directly to the worm shaft, the worm being cut out of solid steel and meshing into a hobbed bronze wheel turning on a shaft mounted on babbitted bearings. The projection at one end of this shaft, having mounted upon it the friction coupling, controls the working shafts. The opposite end is coupled to a short length of shaft which carries a chain wheel similar to a sheave in a chain hoist and from this point by means of a welded link chain made endless is turned at an angle to the main working shaft, the supplementary shaft for operating the valves in the lock gates. This shaft is supported on bearings secured to the coping of the lock and placed about ½" above its surface and continued under the bridge on the lock gate, a universal opposite end is coupled to a short length of shaft which carries travel of this joint is minimized.

The arc of the circle through which this coupling passes is provided for by a swivel box carrying the end of the driven shaft and the travel in and out is allowed for by having the chain sheave run free on the shaft, except when engaged by a jaw clutch keyed to the shaft so as to allow the shaft to run in and out as it passes through this arch, and engage or disengage the clutch at the proper time for controlling the valve mechanism. The clutch being disengaged, allows the driving sheave to run loose on the shaft; and the shaft itself remains idle during the time the gate is open and is only put into operation when the gate is swung to the closed position.

The valves are operated by bevel gear reversing mechanism, which allows the operator to either close or open the valves in the gates by throwing the shipping lever, which engages a jaw clutch with one of the bevels required to operate the valve stem in the desired direction. The travel of this stem, however, is limited by an automatic stop, consisting of a loop and bell crank operated by a pin in the cross head travelling with the valve system so that at the lower or upper limit of travel, the pin trips the bell crank connect-

ing with the shipping lever so as to throw the clutch out of engagement with the bevel gear which produces the motion.

This mechanism permits of much more rapid lockage than could be carried out by hand, and reduces the necessary force of lockmen to one-half the crew formerly required.

LOCKAGES.

While the usual lockage is, perhaps, a familiar sight, many possibly do not understand it, and a short description will not be out of place.

Let it be assumed that a barge is proceeding up the canal, following another which has previously passed in the same direction.

The lock would, of course, be full of water up to the level of the section above. As the barge approaches the lock, the lockmaster starts the motors at the lower end by means of the starting switch on the switchboard in the lock house, and two of the lockmen proceed to the lower gate and open the valves, which allows the lock to empty into the lower reach; the mechanism is started on all four valves one after the other. One of the lockmen crosses to the south side and the other to the north side. The mechanism operating the valve stems continues to operate until the valves are wide open and the pin trips the operating mechanism, leaving the valves in this condition until the water within the lock has reached approximately the level of the lower reach.

The lockmen on each side of the canal then throw in the friction clutch which connects by means of a short shaft to the pinion meshing into the large spur wheel on the winch. This winds up the slack on the chain which runs through the chain well over a roller and out to a hook about four feet above the sill at the outer end of the lock gate.

As soon as the slack is wound up, the chain commences to move the gate, opening it until it leaves the passage free for the entrance of the barge into the lock. As soon as the boat is moved into position and made fast, the gate is closed by throwing in the opposite clutch, which operates the winch at the opposite end of the shaft and closes the gate—the clutch on the first winch being released, of course, allows the chain to pay out as quickly as required to permit the gate to close.

As soon as the gates are closed, and the clutch operating the shaft which drives the valve mechanism has moved into engagement and started the valve driving mechanism, the lockmen throw the lever starting the two valves in each of the lock gates to close and immediately walk over to the other end of the lock; before they reach it, however, these valves have closed and the tripping mechanism

has thrown the clutch out of gear. The valves in the gates in the upper end of the lock are then opened in a manner similar to that described in connection with the opening of the lower gates, allowing the barge to proceed on its journey.

WEIRS.

To keep the various levels of the canal normal, on account of excessive flow of water from above or any heavy draught of power used on a level or by lockages, the flow of water has to be compensated for by adjusting the weir gates.

These gates are operated by worm and segment, or, in some cases, by raising or lowering the valves in a manner similar to that on the lock gates, the operating of which is carried out in much the same way as described in connection with the gates.

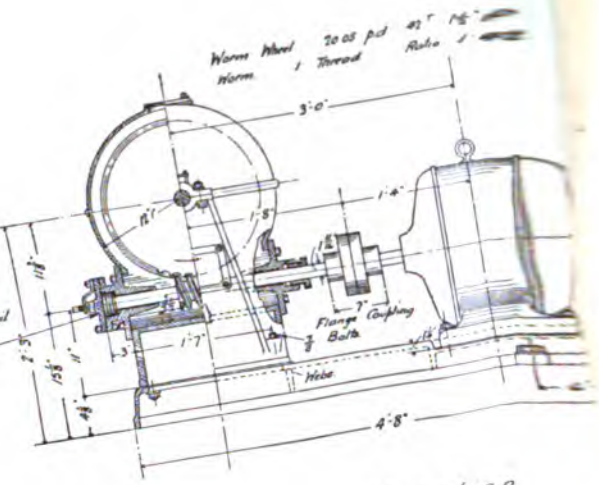
As there are a number of weir gates or valves which must be capable of independent operation, provision is made by means of a double jaw clutch engaging with either one or the other of two bevelled gears on a horizontal shaft which meshes into a third bevelled gear on a shaft of the worm for operating the segment which drives the valve stems.

The operator only has to throw the clutch into engagement so as to move the valve in the desired direction and as soon as the gate has opened or closed sufficiently for the purpose of regulation, the lever is thrown out of engagement with the gear. A friction clutch is placed between the shaft of the worm wheel driven by the motor so that in case of accident resulting in jamming any of the parts, the friction clutch will slip before any serious breakage occurs.

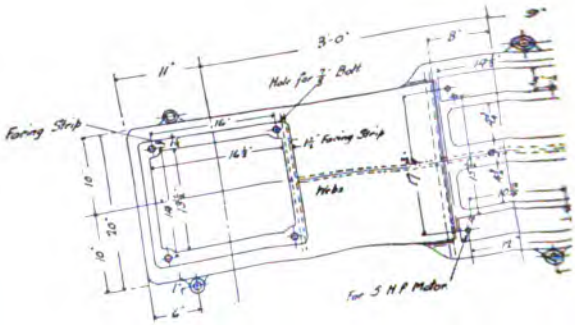
BRIDGES.

The equipment for the bridges is operated by a motor driving the mechanism through worm gears, the same power unit being utilized as for the operation of the lock gates and weirs, an extension of the interchangeable idea. Aside from the first speed reduction, however, the gearing is quite different, though in the case of both the Mille Roches and the Stormont bridges the arrangement is worked out on similar lines.

The bridge at Mille Roches is 179 x 12 and has the motor swung under the bridge just outside of the turn table, being counterbalanced by weights at the opposite end of the bridge. I Beams support the motor and worm gear case, the shaft of which drives the gearing communicating the motion to a pinion meshing with the rack which turns the bridge.

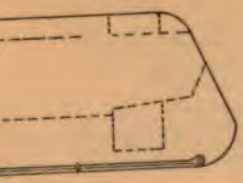


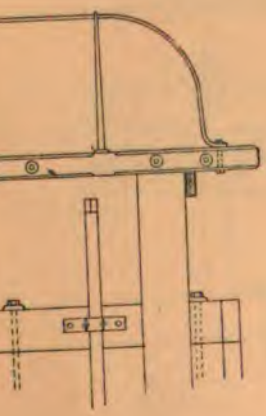
Elevation



Plan of Base.

NWALL CANAL
ENT OF MACHINERY
RATING LOCK-GATES
ELECTRIC POWER.
Scale.





ONWALL CANAL

MENT — OF — MACHINERY

NG WEIR-GATES OF LOCKS

G ELECTRIC POWER

- Scale -

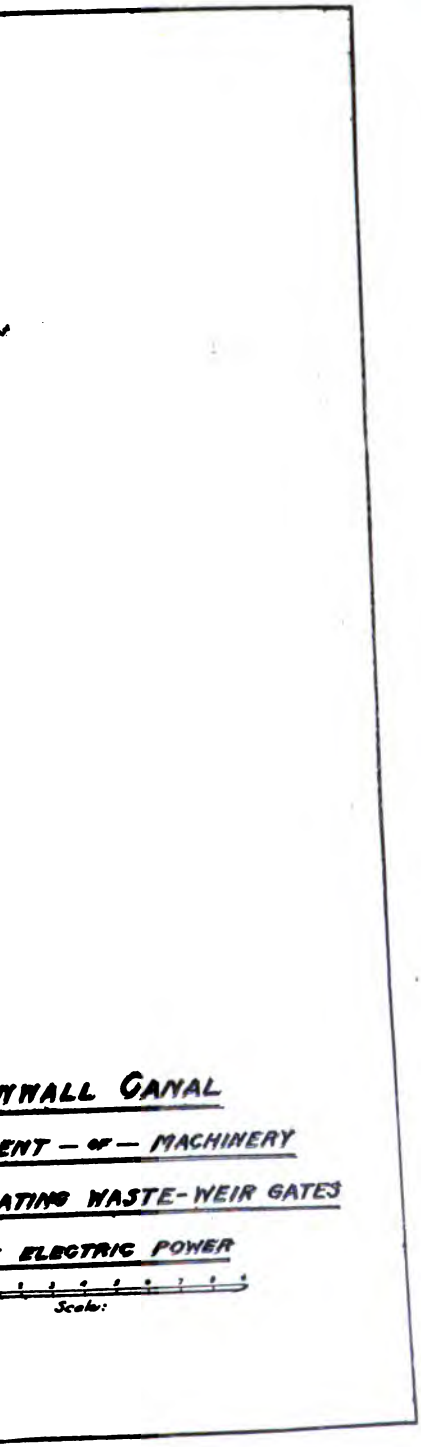
ALL CANAL

T — OF — MACHINERY

TING LOCK-GATES

ELECTRIC POWER.

Scale


WALL CANAL
ENT — OF — MACHINERY
ATING WASTE-WEIR GATES
ELECTRIC POWER
Scale:

CANAL

— MACHINERY

WING-BRIDGES

IC POWER

. . . . .

A friction clutch communicates the power from the motor driven worm shaft to one or the other of a pair of bevels turning the bridge in whichever direction the operator desires The clutches are operated by two removable levers coming up through the bridge floor so that the bridge tender has ready control of both.

To swing the bridge, the operator first starts the motor, then throws the lever which withdraws the bolts unlocking the bridge. One of the clutch levers is then operated so as to engage the bevel gear required to turn the bridge in the desired direction for opening. The friction slips for a while until it gets the bridge under motion, then it swings rapidly until it is nearly open when the operator uses the other friction clutch (which tends to turn the bridge in the opposite direction) as a brake to retard the speed and gradually bringing the bridge to rest in the open position.

The reverse motion is used for closing and is operated in very much the same way.

The control of the Stormont Bridge is very similar to that of the Mille Roches Bridge, the only difference in the mechanism being that the power unit is mounted inside the drum of the turn table on I beam frame, which does not require to be balanced.

The power is communicated with a large intermediate gear so as to reach the gearing originally utilized in turning the bridge by hand.

The Stormont Bridge is very much heavier than the Mille Roches Bridge, but the operation is very satisfactory. The normal full load current is only exceeded for a few seconds in starting.

As in both cases, the motors are mounted under the deck of the bridge, little protection is required but a galvanized iron cover is provided so that drip from the underside of the planking is prevented from reaching the motors. The motors alongside the locks are also protected with easily removeable galvanized iron hoods or covers. This is the only protection from the weather, which has been provided for the motors, and they have been left in their position without any other cover for the last two winters.

The hardiness of the motor used has been well demonstrated by the fact that the motors start up every season without any trouble. The only serious trouble with the machines occurred after a heavy storm which brought the 11,000 V. primaries in contact with the 550 V. secondaries for a few seconds, resulting in a burn out of half a dozen motor coils in one of the machines. Lightning has occasionally given slight trouble but nothing of a very serious character has occurred.

DISCUSSION.

Mr Herdt. Prof. L. A. Herdt said that there was one point which his paper had not touched upon, which he would speak of before the discussion went on.

The question was, What is the advantage of using electric power on these canals? The principal advantage was the saving in cost of labour. With the old winch and chain system, to do the work two men per winch were required—that is four men per lock, eight men per double lock. Now, on the Lachine Canal, it was proposed to handle the work with the electrical equipment with four men per double lock, quite an appreciable difference in the cost of labour. The capacity of the canal was practically duplicated, as it could be used as readily at night as in the day time, and the time required for opening the gates had been reduced to one minute, instead of a minute and a half.

Prof. Herdt also added that when the Montreal Light, Heat & Power Co. were short of power, the Lachine Canal Electric Plant furnished them with 150 kilowatts, running this station in multiple with the power company's stations.

Mr. Leonard. Mr Leonard said there had been some experiments made at the Cornwall Canal. Two men were placed on each winch and an effort made to open the gate as fast as possible. The men had turned at a pretty lively pace, a good deal faster than usual, and the gates had been opened in just one minute and a half. The electric power had been applied and the gates opened in just one minute. The water had to be regulated, however, and if too much water were allowed to pass, damage might result, so that the opening of the gate was the only way that time could be saved. That had been accomplished, and half a minute saved. The process had also saved labor and reduced expenses. Instead of four men, but two were required, so that the 24 hours could be divided into two watches, giving the men some time to themselves, whereas formerly, the four men were required to make the lockages, and were on duty the whole twenty-four hours, catching sleep as best they could between times.

Mr. Thornton. Mr. K. B. Thornton said the Montreal Light, Heat and Power Company had used power from the Lachine Canal for several months, running the series arc lighting from that station, by building a shanty on the bank of the canal, and pulling in three transformers and regulators,—connecting one to each phase. He wished to know how many arc lamps there were on each circuit on the

and whether spark gaps on individual lamps or Mr. Thornton.
ıs were used on the arc circuits, and if there were
ble in operating them. He also wished to know if
s were used on the lamps, and if the placing of
line and spark gaps would reduce troubles from
way.

l replied that there had been a little trouble with Mr. Leonard.
the circuits ran from 20 to 100 lamps per circuit.
at present there were 85 to 90 lamps per circuit—
ble it had run with as high as 110 lamps on a cir-
ressed a very high voltage on the line, and the
t a severe strain on everything. Mr. Leonard
e had occasion to lay out another plant of similar
ought he would put in fifty lamps per circuit in-
ndred.

made any special provisions against lightning, ex-
the cables at the point where they passed under
one bank to another and at the piers of the bridges,
ightning arresters. There had been a breakdown
cable, but it was cable which had been designed
temporarily used on 11,000 V. He thought light-
t the crossing had helped. There were lightning
station on each circuit, and the gaps were cut
making the resistance to ground across the gaps
r. There had been no trouble except the breaking
ulation in the arc lamps due to the excessive strain.

said he thought that the freedom from trouble Mr. Herdt.
the Lachine Canal, was on account of the iron
g the canal, and the pole line paralleling the canal.

nan said he had noticed that there seemed Mr. Ross.
able number of friction clutches in operation. He
rk on the friction clutches would be very severe
reverse clutch for stopping, if there is a brake,
bly severe. Friction clutches were troublesome
would like to ask Mr. Leonard if he had experienced
this connection.

l replied that he had had absolutely no trouble Mr. Leonard.
the friction clutches. In the case of these clutches
d liberal capacity, using a clutch pretty large for
had to do. Then, further, he thought the
ry good one. The mechanism operated by the press-
ast iron plates against another disc having wooden
—the wood wearing on the ends—i.e., the pressure
e end of the wood fibres. It had given great
d there had been hardly any trouble with it. The

Mr. Leonard. clutches would slip under a certain pressure, and this was done in the operation of checking and reversing the bridge—one of the neatest operations imaginable. The bridge started up slowly, came up to full speed, and then swung into place, slowing down and coming to rest as nicely as possible.

Mr. Thornton. Mr. Thornton asked what kind of wood was used for pins, and whether they were put in stearic acid for insulating or preserving purposes? When the line was built from Chambly to Montreal, the pins were boiled for several hours in paraffine. Careful observations had shown that the paraffine had evaporated to a great extent, and it was a question whether it paid to treat the pins at all.

Mr. Leonard. Mr. Leonard answered that the difference between paraffine and stearic acid was that paraffine exposed to the sun would evaporate. Stearic acid dried very hard, and held its body well. It stood the weather, and at the same time formed a good coating, which was an insulator and worked very well. The pins were hickory—that is, most of them. The supply had run out, and some locust pins were used, they were all treated in the same way, boiled in stearic acid, for perhaps half an hour. It seemed to fill the pores of the pin. Stearic acid was a good preservative and a good insulator at the same time.

Mr. Herdt. Prof. Herdt stated in connection with friction clutches that he had a sketch of the proposed mechanism for operating the bridges on the Lachine Canal. It was a very simple method and very similar to the apparatus used in connection with the operation of the bridges spanning the Soulanges Canal. The sketch showed method employed and the special friction clutches in use. This apparatus was working very successfully.

Mr. Leonard. Mr. Leonard stated that he did not believe in the practice of reversing the motor.

Mr. Burson. Mr. Burson said the motor was reversed to slow down the bridge. It was done by the throwing over of a switch.

Mr. Walbank. Mr. W. McL. Walbank asked Prof. Herdt if he had any idea what the cost of maintenance was for the arc lamps along the Lachine Canal?

Mr. Herdt. Prof. Herdt answered that this had not been figured out yet—that the lamps had not been in operation a sufficient length of time. According to the reports of the inspectors, there were on an average 99 lamps burning out of a hundred every night. He had gone over the circuits many times personally, and there had been little trouble with the arc lamps.

Mr. Walbank. Mr. Walbank wished to know how that compared with the Cornwall Canal.

Mr. Leonard. Mr. Leonard replied that on the Cornwall there had been some trouble with 10,000 V. circuits. Those on the Lachine Canal were operated at 2,400 V. only.

The Chairman asked what series transformers were used. Mr. Ross.

Prof. Herdt replied that on the Lachine the floating coil was employed. Mr. Herdt.

Mr. Walbank added that at Cornwall the G.I. was used. Mr. Walbank.

Mr. Ross said there was another feature of the application of electricity to canal service, which he thought would have to be taken up next year—that was towing. It was a most important point, although he believed it has not yet been gone into much on this side, though it had in Europe. There were some experiments being made now in the States, and if they made as much of it as in Europe, we might see an extension of the present plants. Mr. Ross.

Mr. Leonard said that a few experiments had been made on the question of towing on the Cornwall Canal. A 40 H.P. motor was put on a Gypsy winch and tried pulling some barges in, the Government yacht "Alert," with a full head of steam, pulling against it at full speed, was pulled into the lock. The experiments were made with a view to winches for pulling boats into the locks instead of allowing them to enter under their own steam, so as to prevent their going through the gates in case of anything happening to their reversing gear. To provide against the danger, winches were proposed at all the locks, warping them into the lock instead of allowing them to go through with their own steam. Towing electrically certainly promised to be a very interesting question, but, as Mr. Ross had stated, it was a problem which has not been gone into very extensively on this side as yet. Mr. Leonard.

Mr. Ross thought that the idea of the winch is a very good one, as the barge "Ocean" used to go through the gates about once a week. Mr. Ross.

General Section.

March 31, 1904, Mr. W. McLea Walbank in the chair. In the absence of the author the following paper was read by Mr. J. G. G. Kerry:—

PAPER No. 209

THE SHUBENACADIE RIVER BRIDGE—MIDLAND RAILWAY.

By J. J. Taylor, M. Can. Soc. C. E.

PART I.

The Midland Railway of Nova Scotia (the air line between the towns of Truro and Windsor—fifty-eight miles long) crosses the Shubenacadie River on a single track bridge, known as the Shubenacadie River Bridge.

The Shubenacadie River empties into Cobequid Bay, and may be said to be really an arm of the Bay of Fundy. The point of crossing is five miles up from the mouth of the River, and near the village of South Maitland. The river at the point of crossing is about 1,220 feet wide—high water mark to high water mark.

The tide at the bridge site has a maximum range of 32.7 feet—extreme low to extreme high water. There are, of course, two tides in twenty-four hours. The tide begins to run in about two and one-half hours before the time of high tide. About five hours after the time of high tide the water has largely run out again, thus leaving the sand flats bare twice in every twenty-four hours for about five hours each time. When the tide is out only the fresh water flow is left, and the width of the river (channel) is then only about two hundred feet.

Between certain elevations of both flood and ebb tide the current is very swift, reaching a velocity of ten to fourteen miles per hour on the spring tides. There is practically no still water in the river at this point, and at the time of high water there are never more than forty minutes in which boats, scows and materials can be handled on the river.

One of the many peculiarities of the tide was, that just after it had turned from flood to ebb, and when the current was running down quite swiftly along each shore, and the water lowering vertically, the current was still running up quite swiftly in the middle of the river. This continued for about one-half hour after the ebb tide set in. With the coming of the tide we had what is known as the Bay of Fundy "Bore," but not reaching a greater height than

Photo 1.

arely that high. (The writer has seen the "Bore" t Moncton, N.B.)

aspect of the Shubenacadie River at the bridge site otos 1 and 1a. These show the tide about three

for the substructure was let to the Engineering New York (since gone out of business). They com- ons May 1, 1899; suspended for the winter Dec. 1, May 3, 1900; and completed Dec. 12, 1900.

letermine the strata and locate the bed rock were manner described in specification, the following t therefrom :—

egard to borings.—They were made under Mr. A. G. supervision, with a rig owned and operated by naid & Co., of 162 Barrington St., Halifax. It was ature pile driving arrangement with a 150 lb. dolley iding on the drill. It was found impossible to get bout the drill through the compact gravel, etc.; and drill was turned as it went down, but drove very e or twice the drill went down for short distances perhaps striking a streak of clay, but the gravel, compact, especially on the eastern half, growing one approached the channel. In the deepest place ours to drive the drill twenty feet, with four men on es."

ing table shows the elevations of the rock line ese borings and shown on the accompanying section d the actual elevations :—

k Line on Con- Profile.	Rock Line— Actual Built On.	Distance Below Rock Line Shown on Contract Profile to Actual Rock.	Remarks.
—	—	—	Rock bare.
—	—	—	" "
07.10	102.30	4.80	
01.50	100.00	1.50	
17.50	104.91	12.59	
24.20	122.00	2.20	

many lessons that this work taught was the great accurately designating the strata through which it

becomes necessary to go to reach the bed rock, and to accuratel determine the elevation of the bed rock.

If the contracting company for this work had not been ove taken by financial difficulties just before they completed the wor the probabilities are that expensive litigation would have been th result of inaccurate borings.

It will be noticed, however, that the rock line shown on th contract profile is marked "*Supposed* Line of Rock," and the write might say that the contract with the Engineering Contract Co. co tained a clause as follows:—

"The contract price (lump sum) hereinafter mentioned cove "the works and is based upon quantities indicated on the plan "annexed. Should the total work done by the contractors excee "by more than two per cent. the total quantities indicated on sai "plans, the excess over two per cent. shall be paid for by the Com "pany to the Contractors at the rates hereinafter mentione "Should it be less by more than two per cent., the shortage ov "two per cent. shall be allowed for by the Contractors at the san "rates. The Company stipulate the right to alter the site of ar "of the piers and to diminish their number, provided always, th "new location of any pier be in the Shubenacadie River, on th "line of said Railway; in such case, if the change of the site of "pier should increase or diminish the Contractors' work as show "by said plans and surveys, such increase shall be paid for by th "Company, and such decrease shall be allowed for by the Co "tractors at the following rates, namely:—$15 per cubic yard "concrete in any pier, pedestal or abutment, to cover excavatio "timber, iron, and all other items."

This would seem to provide a basis of payment for any ext depth the contractors might have to go with any pier, etc., reach the bed rock, and it was made to provide for it on this wor

In the writer's opinion it is due to a contractor, and more espe ially when entering upon a difficult, dangerous and expensive wo such as this was, to provide him with accurate data; such as stra through which he would have to pass in order to reach the roc location of the rock; facts relating to tides and currents; and a and all information that would be of a helpful character.

In the first place it is necessary to get all this data in order determine the proper type of structure for any given locality, a afterwards, to design it intelligently, so that, in getting it, no ex expense is incurred on the contractor's account.

The collecting of this data means money, and the reason th it is not given is nearly always the disposition on the part of m companies to unduly cut down legitimate engineering expenses.

edestals and piers (all of concrete), occur as the Windsor or western end of the bridge :—

nt to center of first pair of pedestals..	34′5″
stals to center of second pair " ..	32′2″
" " " Pier No. 1..	31′5″
" " " " " 2..	42′0″
" " " " " 3..	219′6″
" " " " " 4..	219′6″
" " " " " 5..	219′6″
" " " " " 6..	219′6″
" back of east abutment.. ..	222′6″
	1240′6″

on the above is arranged as follows, beginning estern end of the bridge :—

e between west abutment and pier 1,
to pier 2 (for the passage of small craft).
s—pier 2 to east abutment.

r the sub-structure decided to make the west-e of the river the base of their operations for ixing of the concrete ingredients. Here they set up a stone crusher, laid down the mixing e machinery for the operation of the cableway, orking yard.

ings done by them was to span the river with ay, the line of which was parallel to centre enty-four feet distant southwardly therefrom ; at the bucket, when lowered, would just land piers when they were at elevations halfway w water, but, owing to the batter, would not built up past this elevation.

s supporting the cableway were erected about from high water mark ; the span (tower to ,350 feet.

wo and a half inches in diameter—passed over t of sixty-six feet above high water, and was ound about ninety to one hundred feet back of g secured around three heavy hemlock logs h were laid in trenches some six to eight feet ighted down with stone. These towers were very strongly put together and guyed back. ity was experienced in getting this cable e river and up on the towers. It was

first carried over the eastern tower and secured at that end. When all at work on the flats on the first day of trial, the "Bore" came along, and when the tide went down again, and the flats were bare, eight hundred feet of the cable was buried below five feet of sand. The cable was raised and in position three days later. But, it is to be borne in mind that this does not mean three working days of ten hours each, but snatching a few hours each day when the tide was off the flats.

The utility of this cableway in the building of these piers cannot be too highly spoken off. Men and materials were transferred from any point to any other point on the cableway at all times. It was rarely out of order, and gave endless satisfaction. Indeed, it seems hardly too much to say that the work could not have been done without it.

As previously stated, all abutments, pedestals and piers are of concrete, surmounted by granite bridge seats two feet thick. The total quantity of concrete in this work is about eight thousand cubic yards, and cement averages one and one-half barrels to the yard.

The concrete is in three grades :—

No. 1, used from the rock to two feet above low water. and of the following proportions :—

Cement..	1	
Sand..	1½	
Gravel..	1	(not over ½ inch dia.)
Crushed stone..	3	" " 2 " "

No. 2, used for *facing*—one foot thick—from two feet above low water to under side of bridge seat, and of the following proportions :—

Cement..	1
Sand..	2
Gravel..	1 (not exceeding 1 in. in dia.)

No. 3, used for *hearting*, from two feet above low water to under side of bridge seat, and of the following proportions :—

Cement..	1	
Sand..	1½	
Gravel..	1	(not over ½ inch dia.)
Crushed stone..	4	" " 2 " "

All the concrete ingredients in this work are the very best of their several kinds. The mixing was done by hand, most thoroughly. The cement used was J. B. White & Brothers' English Portland. The sand, clean and coarse, come from Five Islands, on

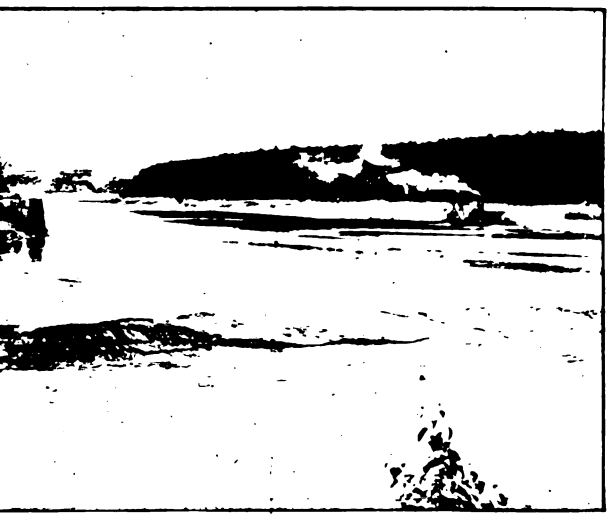
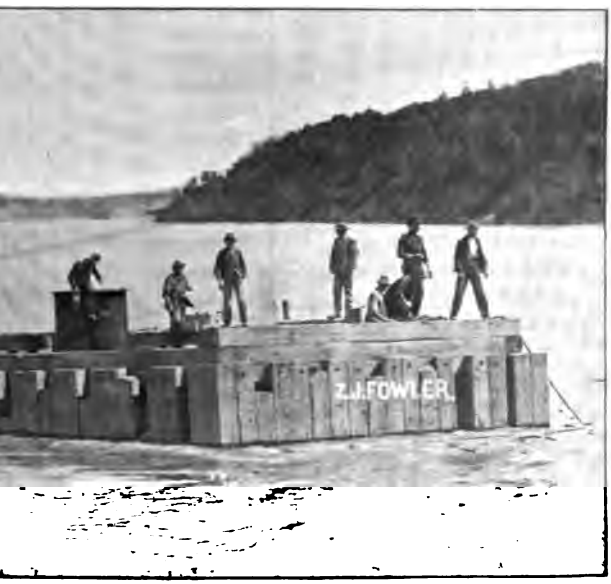


Photo 1a.



how:ng Caisson on way down from shipyard to Bridge site.

d Bay, thirty-five miles from bridge site, and
ners. The gravel came from DeBert beach,
bequid Bay, twelve miles from bridge site,
l screened to size. The stone was quarried
uartzite located in a bluff at the river
r mile up river from bridge site, brought
by scows, hoisted out in one yard buckets by
crushed alongside mixing platform. Some
so picked up along the shores and crushed.
ixed up it was shovelled into one of three one
up and sent to destination on the cable. While
s being sent out another was being filled.
erity with which the cableway worked can be
ng note :—
ne consumed in sending a loaded one-yard
om mixing platform to No. 5 pier (a distance
rning empty bucket to mixing platform, was
r minutes. This was for a run of 1,580 feet,
ng, raising and lowering the bucket.
er for concrete mixing and for boiler use was
the work was often handicapped owing to an
ble supply.
not propose to dwell at any length on the
on used in building the west abutment, the four
and the east abutment. This was *dry* or *shore*
ely simple. Concrete for the first three of these
from the mixing platform to place. Concrete
tment), was sent over on the cable. The east
to rock, but is founded well down into the
overlying the rock. The pile foundation shown
not adopted.
ong in shape, battered 1 to 12 on all four sides,
bay shore spruce permanent casing from low
below extreme high water. (All timber used
below low water is white hemlock). Founda-
x 13 ; dimensions under bridge seat, 6 x 16 ;
ige seat, 15 inches as it carries only a light

d to the two below with ¾ inch square iron
rough 2½ timbers, one within one foot of each
t more than six feet apart.
edestals were built in three-inch deal moulds,

l 6 were founded by pneumatic process. Heavy

timber caissons being in each case carried down through the overlying strata to the bed rock below.

A general idea of the construction of these caissons can be had from plan "A." They were built at an old shipyard about three-quarters of a mile up river from the bridge site. They were built on launchways, christened and launched similarly to a vessel. They were oblong and with a cutwater on each end.

Outside length point to point..62 feet
Inside " " " " ..56 "
Outside " shoulder to shoulder.38 "
Inside " " " " ..35½ "
Outside width.. .. ..24 and 26 feet.
Inside " .. ..19½ feet
Outside height, shoe to top of deck 10¼ " (on 3 tier roof, and
Inside height, shoe to roof of deck 7 " ft. less on 2 tier roof.

They are built of 12 x 12 selected white hemlock, and lined inside (roof and sides) with 3-inch hemlock plank, oakum caulked and air tight, deck floored with 3-inch hemlock plank and oakum caulked; sides and roof double 12 x 12 timbers in case of Nos. and 5.

In view of the possibility of having to sink lower than indicated by the profile, the caissons for Nos. 3 and 4 were strengthened by an additional course of 12 x 12 inch timber on the roof, making three courses in all, the first two being laid transversely, and the upper course laid diagonally, and by 12 x 12 vertical timber, laid close along the sides and cutwaters (making three courses in all), and 1 inch screw-bolted through the two original courses of side timbers at top and bottom of verticals, and drift bolted in between, and also edge bolted (the one vertical to the two adjoining it), with one inch drift bolts.

Photo No. 2 shows the caisson "Z. J. Fowler" for No. 4 pier strengthened as above described, and on the way down from the shipyard to the bridge site. This view shows very little of the caisson proper, as that is submerged. It shows the first three 12 x 12 courses of crib timber above the caisson roof, also the first stepped pneumatic section, the air admission pipe, and the blow out pipe and the upper timbers of a very special feature of these caissons namely:—the mooring crib, to which was secured the heavy steel cables which held the caisson in position against the fierce tides.

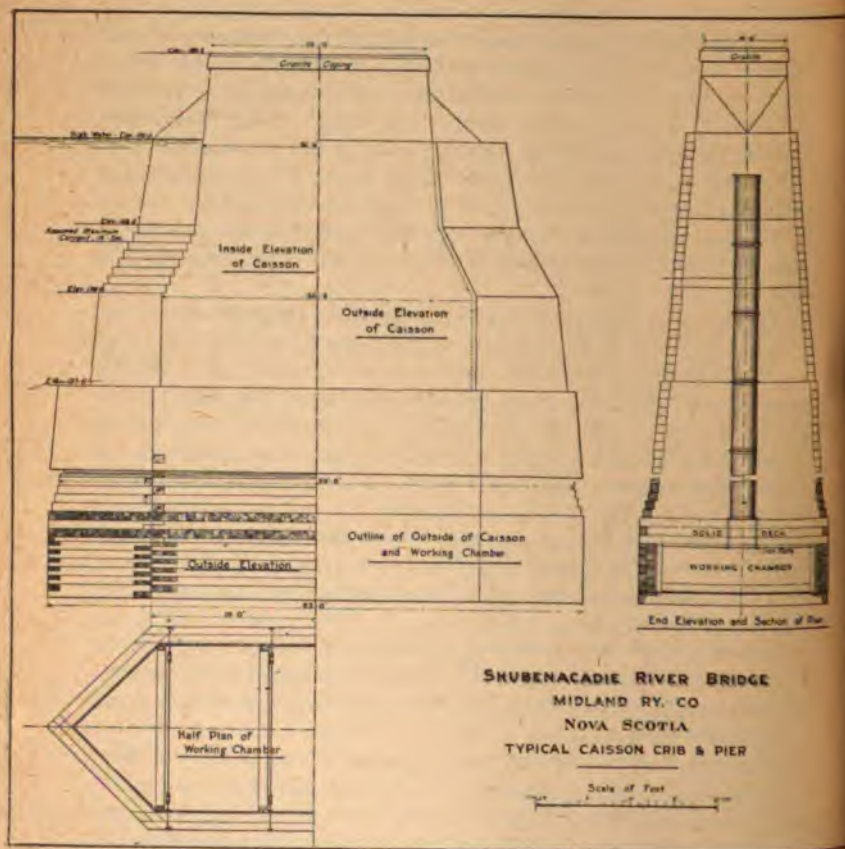
As shown by plan "A," all these caissons were braced against pressure from without by four 12 x 12 (caissons Nos. 2 and 5), and four 12 x 18 and 12 x 24 (caissons Nos. 3 and 4), hemlock timber reaching across the caisson or working chamber, and placed just above the shoe. These timbers were cut about four inches short and any slack taken up by hardwood keys at one end of each brace

erse braces were spaced one at each pair of should-
and two equi-distant between. Any tendency to
y was taken care of by four 1½ inch iron rods pass-
walls to the outside of the caisson, heavy nuts and
side, and adjusted by turnbuckle within. These
d similarly to timber braces ; all as shown by plan

l pneumatic section (eight feet long, 3 x 5, with
or the passage of men and materials, was always
oof before launching. These sections were some-
sometimes twelve feet long. They were bolted
nges to the first or lower tier of roof timbers (and
plan "A"), the upper tiers of roof timbers butt-
, and any spaces being filled with grout.
bers of caissons were drift bolted along the edges to
o the upper courses of the side and cutwater tim-

crib, of which there were two to each caisson (one
of the shaft) was four timbers (or four feet) high
each twelve inch course screw-bolted to the two
e lower two courses screw-bolted through the cais-
upper course was 12 x 12 hardwood, through the
the main fore and aft anchoring cables played.
bers of caissons were bolted together horizontally
ith ¾ inch drift bolts 22 inches long, 3½ feet
er the three inch lining was spiked on inside, ⅞
28 inches long (for two course side) and 40 inches
ourse side) were put through, head, nut and washer

g the caisson to approximate position, four or five
urses of the crib timber were built up on the roof,
quantity of concrete could be put in before finally
son.
ll now endeavor to describe the means and methods
the caissons out to approximate position, holding
finally locating them.
log, stone filled crib anchors were placed on the
to four hundred feet up and down stream of each
ese crib anchors were about 12 x 12 x 12 feet ; 1¼
13 feet long, went through the four corners, two
rneath, around which was secured the ⅞ inch steel
ne up through the stone filling, and having an end
ich was passed the mooring cables from the cais-


Inside Elevation of Caisson
Outside Elevation of Caisson
Outline of Outside of Caisson and Working Chamber
Outside Elevation
Half Plan of Working Chamber
End Elevation and Section of Pier
SHUBENACADIE RIVER BRIDGE
MIDLAND RY. CO
NOVA SCOTIA
TYPICAL CAISSON CRIB & PIER
Scale of Feet

Plan A.

wo previous to the setting of each caisson, a scow
te near its destination, and the caisson ends of the
cables (the other ends of which had been secured
rs) were brought on board the scow ready to be
caisson when she was towed to approximate posi-
These mooring cables were arranged three up and
n of the caisson. The direct up and down stream
nch diameter, and the four breast lines ⅞ inch

aving been towed from the shipyard and beached
the bridge site on one daylight tide, was towed to
tion on the day following at high water, and the
nooring cables passed from scow to caisson and
ast enough concrete to enable it to float on the
following was then put on the roof. This was
of the buoyancy of the large amount of timber in
so great, and the time between tides being so short
concrete could be put on between two succeeding
own.

and tide were at all favourable, and nothing un-
it was finally located on the third daylight tide,
to accurate position until it grounded, by slacking
the different cables ; twenty to thirty men being
purpose.

imperfect description might give the impression
of these caissons on the different pier sites was
trary if was always attended with great difficulty
r instance, in the case of No. 5 : being a trifle late
from the shore they missed transferring all the
rom the scow. Those cables that were secured
it against the strong ebb tide, and it went two
iver before being beached. It was brought back
tide and successfully moored in approximate posi-
succeeding night tide it broke away from the
rning one of the heavy stone filled crib anchors,
the special mooring device on the roof (which up
only been *drift-bolted* through the roof, but which
screw-bolted.) These damages being repaired, it
d eight days later.

f No. 4 (the last one) this caisson was located in
tion as described, and the first batch (or floating
put on the roof. It rode safely over the succeeding
e next day at high water was accurately located,
nded down as described, when, by one of the many
d current, the great force of the ebb tide bore dir-

ectly on the up stream west side. Two of the breast lines parted, and it grounded several feet off position. On the following day the same process was gone through, but the strength of the tide was so great that it could not be pulled into position. The men had just been taken off by the cableway to wait until next day, when one of the lines parted and the caisson turned bottom up. Preparations were immediately made to right it, and the day following in attempting to do so, it turned a complete revolution, parted all mooring lines and went bottom up four miles up the river on the flood tide. It was brought back to the shipyard, the floating load of concrete (which all these upturnings and buffetings had failed to dislodge) was removed, and was righted, repaired, and finally located two weeks later. These are only two of the many similar instances which occurred during the progress of this work.

We have now the caisson located in proper position on a pier site, and ready to proceed downwards through the sand, gravel, etc., to the bed rock, having just enough concrete on its roof to overcome bouyancy and keep it in position.

It was next in order to tow out the machinery barge containing the compressed air and electric light plants, and moor it safely on one side of the caisson, and the derrick barge containing the engine and derrick for hoisting out material from caisson, etc., and moor it on the other side. These were twin barges, each 80 by 22 and 7½ feet deep, hardwood frames, spruce covered, and very strongly built for the work. In the hold of the machinery barge were placed as many oil casks as it would accommodate. These were all connected by piping, and held the water supply for boilers. The air lock was then put on the first steel section, the shift went in, and the caisson started down. The air lock used was a combination man and material, of the Moran type, with the usual double doors and appliances in which the material bucket is lowered and raised through the shaft and lock by an outside derrick, the wire cable playing through a stuffing box in the centre of the outer lock door, which consists of two semi-circular leaves coming together around this stuffing box. Below the lock the material and man shaft was separated only by an open iron grill work, so that it was not comfortable for a man to be climbing or descending the ladder when a batch of concrete was dumped down the material shaft.

The shifts went down in the caissons when the tide was about three-quarters on the ebb, and always came out when the "Bore," or incoming tide reached the bridge site; the time in which no men were in the caissons being the time of the strongest run of the tide. This made two shifts, about five to six hours each in the twenty-four hours—fifteen to twenty-five men to a shift. One shift would

l the shoe, throwing material into the centre
er conveniently near the shaft. The shift
his material, and also the centre excavation,
would be hoisted up the shaft and through
derrick on the barge, and dumped into the
pipes were never used, as the material en-
d.

he 12 x 12 spruce cribbing was being put on
) above the caisson, as shown by plan "A"
over on the cableway and placed in position.
it with electric light and were most comfort-
the heat of summer the pipes conveying the
compressors to caissons were fastened along
below the water line, thus cooling the air
into the caisson.

t down the crib timbers were put on, the con-
air lock was taken off, another steel section
laced, and so on. Great trouble was experi-
green concrete from being scoured by the
was always stopped for some time before
river. The concrete was then covered with
nd large stones placed close around the edges
he surface. Protection planks were also used,
e was lost.

rry large quantities of mud sediment, this
he covering, making it necessary to carefully
he concrete with birch and domestic brooms
creting.

also used in this concrete. The following
ion will show how these were placed:—

ch round bars with hooked ends are to be laid
venient lengths, lapping one foot, and break-
e sets of hooked bars, about a foot from the
side, and carried towards the points of the
sets of longitudinal and cross bars are to be
p of the concrete at intervals of about three
in convenient lengths, lapping one foot and
to be set vertically about one foot from the
ete, four feet apart on the sides, and two feet
r faces, extending from top to bottom of con-

ere from five to eight feet.

eached the bed rock, holes were drilled into it
five feet centres, and two-inch diameter steel

dowel bars four feet long, were grouted in and projected up two feet into the concrete.

We are now on the bed rock with our caisson. The surface of the rock is benched level, cleaned off, and dowel bolts in ready for concrete.

The work of preparing the bottom for, and founding No. 2 pier, although done by pneumatic process, was somewhat different from the others, in that the site of this pier (which carries the draw machinery) was in the channel and on the bare rock, which, at this point was dipping at quite an angle. It was necessary to blast down the high corner during the few minutes at extreme low water, to a roughly level surface ; and to fill in the low corner up to the same rough level with hard impervious clay and stone, to make a landing place for the caisson. The filling in was done by the cableway. The hard clay and boulders which had been excavated and hoisted out of No. 5 caisson, were transferred to No. 2 pier site. Once inside, the caisson was carried down through the rock on the high end, and the temporary filling on the low end. Two or three benches were made on this bottom, and the caisson filled up. This work was so near the shore that the machinery barge lay up on the bank, and the compressed air was conveyed to the caisson by a long pipe.

Photo No. 7 shows the elevation platform built up over the pier, and on a level with the top of the air lock, and used to transfer the concrete (after it was dumped on the platform from the cableway bucket) to the bucket fixed in the lock, which the writer will now describe. It will be understood that this elevated platform is used solely for the handling of concrete going into the caisson. It is passed down by the following method:—

A cylindrical bucket which has a hopper bottom and is about two and one-half feet in diameter, and about eight feet long, is securely wedged into place in the air lock between the lower and upper doors. This hopper bottom is dropped and raised from the elevated platform by a wire rope, which passes up through the bucket, and (by a stuffing box) between the two halves of the upper air lock door to the platform above. When the bucket is being filled with concrete the hopper bottom is, of course closed, as is also the lower air lock door. When the bucket is full the upper air lock door is shut, the lower door opened, the hopper bottom of the bucket tripped, and the concrete falls through the shaft on to a platform at the bottom, and is shovelled to destination and tamped. This cylindrical bucket is stationary during the process of filling the caisson. When this is completed the air

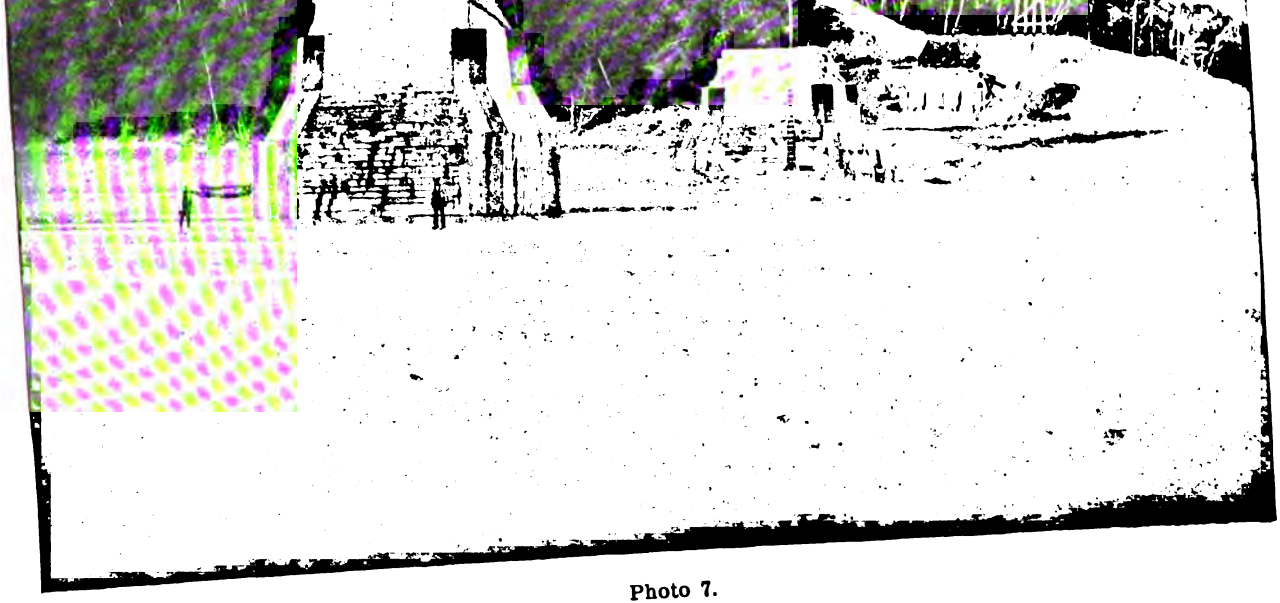


Photo 7.

the shaft filled up. From three to five sections
d in each pier.

placed in the pier proper by transferring, with
arge, the loaded bucket, which was dropped on
om the cableway.

e cribbing was carried up to high water, each
to the two below it with three-quarter inch
s going through two and one-half timbers, one
end of a stick, and not more than six feet

tie rods, one and one-quarter inch round, went
hrough the side timbers at every fourth course
he concrete—head nut and washers on outside
in. Concrete from high water to under side of
plank mould, afterwards stripped off.

were two feet thick, of Halifax granite. The
5½ and weighed 7¼ tons, and were set by the

piers, from three feet below low water to high
ed with 6-inch birch, placed vertically and
b timbers with five-eight inch steel drift bolts
. The nose and shoulders of cutwaters, from
water to high water, were protected from the
-eight inch steel angle plates, drift bolted to
imbers with three-quarter inch drift bolts fif-
ntersunk heads, and lapping three feet on each
ulders.

ater batters are shown by plan "A" and photos
obably thought by the designer of these piers
lat intermediate batter would enable some of
reak of its own weight. Photo No. 9 shows
the river at low tide. In the judgment of the
d have presented a much better appearance and
e and substantial, if a straight cutwater batter
had been used.

langerous character of this work the fatalities
were drowned in caisson No. 5, through the
xperience of a lock tender. Both doors were
same time, the air, of course, escaped, the water
was a stampede for the shaft. Most of the
ur men were caught.

owned by losing his balance when wheeling
to a scow over a gang plank. He was swept
nent by the current.

Before closing the first portion of his paper, the writer wishes add a tribute to the executive men and the rank and file who carri this most difficult work to a successful conclusion. The men charge were full of nerve and determination, and were most sourceful. Two of the best foremen have since lost their lives wh in the discharge of their duties on pneumatic work in the Unit States.

PART II.

Superstructure.

The second part of this paper will be a short description of t methods used in erecting and floating in the steel spans.

Between pier No. 2 and the east abutment there are five spa each 215 feet long between end pins. The spans are of the p connected camel back truss type, each span weighing about 160 to and were built, erected and floated in by the Dominion Bridge C of Montreal.

The two spans between the east abutment and pier No. 5 we erected on steel false work during the autumn of 1900. On accou of the swiftness of the current and force of the tide it was n thought prudent to use false work farther out than pier 5, cons quently the remaining three spans, between piers 5 and 2, we erected on shore on wooden false work, and, at high water, float to position on the large twin barges, which had previously be used by the sub-structure contractors as a derrick barge and machinery barge, and which have been described in part I. of th paper.

The Dominion Bridge Co. selected the eastern or Truro side the river as the base of their operations owing to its having ra connection with Truro. There was also a convenient area of lev land imediately south of the east abutment, which offered a goo site for assembling and erecting the steel. They constructed tw narrow wharves exactly parallel to each other, and roughly parall to the centre line of bridge. These wharves each projected 130 fe from high water mark out into the river. They were 215 feet apa centre to centre. They each consisted of 10 narrow pile bents. 14 feet centres, four piles to each bent, X braced and double capp and with five lines of 20 inch I beam stringers along each whar surmounted by wooden ties and double lines of rails on each whar Top of rail, six feet above high water.

A heavy eight-wheel truck was set up on the rails of eac wharf. The shoes of each span rested upon these trucks. Woode false work supported the span between the parallel wharves durin erection. As soon as the span was erected the trucks with the

Photo 8.—No. 5 Pier.

Photo 9.—Ice Formation.

Photo 10.

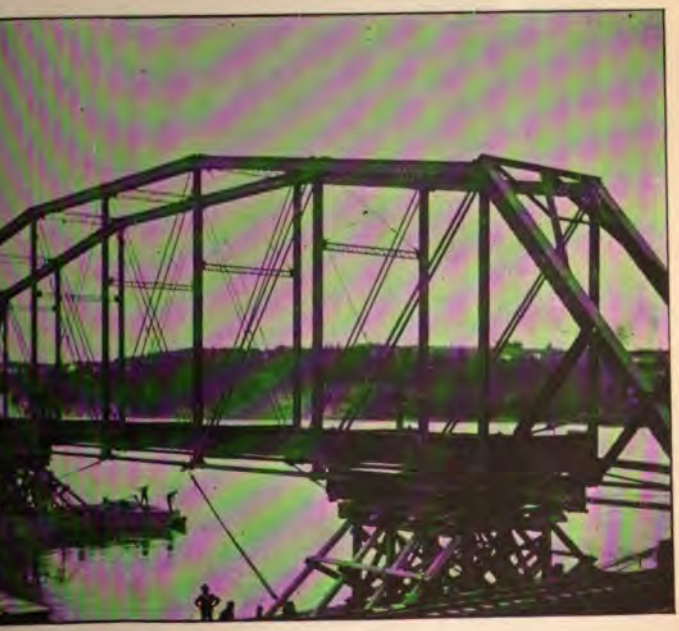


Photo 10a.

out to the river end of the wharves. The two
h supporting false work had been erected, were
per places underneath the span, and all was ready
n off the trucks.

nbered that two spans between the east abutment
ere now in place on the piers, and the railway
m.

now endeavor to describe the floating in of the
s 4 and 5:—

d winding engines (engine No. 1 and engine No.
vy trucks of standard gauge, were in position on
ed, namely: the one between piers 5 and 6, engine
and secured about forty-five feet back from pier
2 similarly secured about forty feet back of engine
wire cable was carried from the drum of engine
nd of this span near pier 5, passing over two 18″
rectly to the nearest end of the floating span and
his cable from drum to floating span was about
long. The second ⅞ inch wire cable was carried
engine No. 2 along past the down stream side of
the down stream end of pier 4, where it passed
sheave and thence directly to the farthest end of
and was there secured. This cable from drum
as about 940 feet long. The longest lengths of
namely, the lengths from piers to ends of float-
the river bed. The area over which they would
assage of the span from the parallel wharves to
roughly levelled and carefully cleared of all
which the cables might foul.

moved out from between the ends of the parallel
last of the flood tide was still running quite
er, in order that the two barges bearing the span
away from the bridge, and would be slowly and
back to destination by winding up the cables on
ums.

the Dominion Bridge Co. considered this to be a
sing tug boats. However, one tug boat was in
floating in of each span, in case of emergency.

(the one between piers 5 and 4) was floated to
30, 1901. It was raised off the trucks on the
y the two barges at 11.40 a.m. At 12.04 p.m. the
e two ⅞″ cables), started out from between the
el wharves, and in eight minutes (or 12.12 p.m.)
etween the piers and ready for the tide to lower

it down on the bridge seats. At 1,22 p.m. the four shoes rest on the bridge seats. The floating in of this span is well shown the photos numbered 10a and 11. These photos are also typical the floating in of the other two spans. It will be noticed that eig minutes is not long for a task such as this. The succe ful passage of this span from the parallel wharves to its d tination had considerable good fortune attached to it. This do not, in the slightest degree, reflect on the foreman in charge of t work or the men under him. The foreman was a thorougl capable and careful man, and was well supported by his men.

Previous to this floating span starting out from the paral wharves for its destination, both the ⅞ inch winding cab (between the last sheave and the end of the floating span) had been lying on the river bed, but had been temporarily suppor along the greater portion of this length by being suspended fr the lower chord bars of the two spans already in position. soon as the floating span had cleared the ends of the paral wharves, the shorter length (i.e., the length going to the near end of floating span) was dropped from the lower chord bars i the water. The sag of this cable as it dropped and sank caus the end of the span to which it was attached to start violently f ward. Just about this time the longer length (i.e., the leng going to the farthest end of floating span) was dropped, the sag which caused the other end of the span to do the same, so that floating span, instead of moving out regularly and uniformly—b barges at the same time—zig-zagged (as it were) to position, a it might almost be said that the two winding engines did little e than wind up the slack of the cable, as first one barge and then other shot forward, being moved nearly altogether by the saggi of the cables.

After the various spans were in between the piers and ready the tide to lower them on to the bridge seats, they were kept to t centre line of the bridge, that is, to the correct lateral position, the ebb tide causing the sides of the spans to bear and slide do against four heavy vertical timbers (two on each pier), which h previously been secured in the correct positions, and they were k to their correct positions longitudinally by four men with bars each shoe, the span being moved longitudinally with great ease.

A few minutes after the spans rested on the piers, the t barges dropped away on the ebb tide, and were beached just bel the bridge and brought back on the flood tide following, ready take out the next span.

The span just placed was then completed, the track laid, and t winding engines advanced one span length until they occupi

Photo 11.

espect to pier No. 4 that they had just done
5. The ⅞ inch winding cables (which, of
), were again arranged as has been describ-
hat they were allowed to rest on the river
d not looped up along the bridge as before.
of the river bed over which these cables
cleared of obstructions and all made ready
en piers 3 and 4), which was floated in Aug.
most successful of the three—everything
It was raised off the trucks on the parallel
ges at 12.19 p.m., started out from between
wharves at 12.47½ p.m., and at 1.20 p.m.
the piers, ready for the tide to drop it on
hich it rested at 2.16 p.m. This span was
nding engines once more advanced and
made ready for drawing out the last span

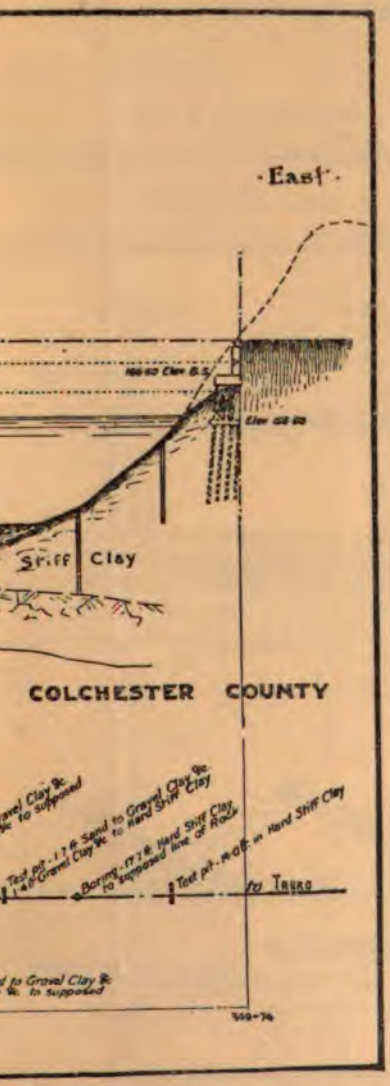
ssfully floated out Aug. 28, 1901, record as

on the parallel wharves by the two barges.
om between the ends of parallel wharves,
etween the piers ready for the tide to drop
.05 p.m., where it landed at 12.52 p.m.
he longest distance to travel; the cables
on were, of course, longer than those used
, and had a greater area of river bed over
ithin this area was the remains of one of
h one of the caissons had been moored. It
ge this obstruction, and it was planked over
gly, the cable would slip over it during the
m shore to destination. This is just what
d when this span was in the middle of the
endidly, it suddenly stopped. One of the
d crib anchor. Several minutes were lost
his line. This was found to be impossible,
the floating span end. The tug boat (which,
d) came alongside this barge, and the span
; the tug taking one barge and the other
emaining cable. Had the tug boat not been
e that this span would have been wrecked.
e writer it would have been much better in
er, safer and quicker—to have moved these

barges, with their load (from the parallel wharves to between t piers) by two tug boats, one to each barge, but this was mo clearly shown *after* than *before* the work was done.

The plans showing the arrangement by which the spans we erected and moved, are from the office of the Dominion Bridge Co

dr Johnson.



DISCUSSION.

Johnson said Mr. Taylor's paper was a very fair and Mr Johnson.
of this bridge, which, because of the great range of
ess of its tidal currents, was a work of unusual diffi-
uthor spoke of one peculiarity of the tidal current,
water was running up swiftly in the middle of the
unning down along the shore. This down-stream
e had escaped his notice and was probably confined
ow margin along the banks.

ing the conditions at the site of this bridge, he was
in all tidal rivers, the up-stream surface current
nsiderable time after the water began to fall. At
this was very noticeable, the surface current
eam for fifteen to twenty minutes after the water had
hest stage, and in fact, while it had fallen from one
The explanation of this action was probably that the
bottom of the river met with resistance from the
f the river bed and was retarded, stopped and com-
out while the upper stratum was still going on at
eed.

of the water at high tide was a point to be seriously
onnection with the floating of the spans, and a little
work was commenced a reliable man was stationed
aylight tides; to note the elevations at five-minute
ote how long after high water the surface current
to note the duration of the slack water period, and
ce current commenced to run down the stream. The
e observations showed that the quickest rise of tide
feet in ten minutes, though on another occasion a
in one and a half minutes was reported. The aver-
high water mark was reached until the surface cur-
ceased, was about fifteen minutes; then there was a
aps ten minutes slack water and then the down-
began. Aside from this record of the tide, for about
rd was kept and plotted of the high water periods of
at the foreman in charge of the work might know
h blocking to place between the spans and the tres-
ws. The records showed the high tide from week to
h to month to be fairly regular, though influenced by
nd force of the winds in the gulf and bay.

stated in his paper that the floating of the first span

was attended with considerable good fortune, it being towed irreg
iarly to position by the weight of the cables as they sagged to t
bottom of the river. This was reported at the time, but on inve
tigation it was concluded that the unexpected movement of t
span was not due so much to the weight of the cables as to t
force of the wind, which blew diagonally down the river and caug
the upper portion of the truss fairly, while the lower part w
sheltered by the bank and the force of the wind was not appreciat
by the men below.

Experience in floating spans had shown that only a very mode
ate breeze was needed to overcome a very considerable current,
the combined surface of the trusses formed a large sail area, o
posed to the wind.

It was appreciated from the first that a great deal of risk atten
ed handling these spans by cables dragging on the bottom of t
river because of the chance of the cables fouling some obstructi
that could not be seen at low tide and removed. The bottom
the river was a bed of sand several feet in thickness, which was a
parently picked up and carried up-stream by each flood tide a
brought back and re-deposited with the falling tide. Logs or oth
obstructions covered by sand at low tide could not be located a
the chance that a cable would foul some such obstruction had to
taken. Whether the cables attached to the third span did foul
the crib anchor mentioned by the author, or on some other o
struction, was not known.

The author's suggestion that it would have been better to ha
handled the spans by tugs instead of hauling them into position
cables was a very natural one and this course was very careful
considered, but at this location suitable tugs for the work were n
available, and it was uncertain if they could be procured prompt
when wanted. Experience had shown that few tug men could
induced to make fast alongside of the barges carrying a span b
cause of fear that something would happen and the span co
down on top of them, and it was considered better to take t
chance of fouling cables rather than the chance of having no t
when wanted and tug crews without confidence enough to get und
the spans and handle them properly. As a measure of safety
case of any mishap, a tug was engaged to be present and it d
good service when a cable fouled at the placing of the third span

Mr. Butler. Mr. M. J. Butler said he thought Mr. Taylor's paper describ
probably the most difficult superstructure that had ever been ca
ried out anywhere in the world. He stated that he was down at t
Shubenacadie River and saw the work being carried on, a
thought no one from the way in which it had been described cou
appreciate the dangers and difficulties encountered on the wor

e appreciated by those who were on the ground. Mr. Butler.
ainly great credit due the men who carried out the
ad been completed in a successful manner.
at there were a few points in the paper which he
nake comment upon. First, as to the absolute ne-
ing accurate borings and of getting the proper facil-
g these borings. Certainly the methods specified in
d not secure accurate borings under any circum-
not an easy operation and called for a very consid-
of skill and care, and he did not think it could be
plant as described here.
re was a term used on page 192 "Bed Rock" which it
sting to know the meaning of. It was one almost
t in litigation almost every time it was used. Cer-
"rock" had a clear significance in the minds of every
e qualifying word "bed" did not describe any more
was; and what was bed rock? It was a sure road
led to difficulties, misunderstandings and trouble for
If it meant anything, it meant rock resting "in situ,"
ate or bed. If it didn't mean that, it meant nothing,
escribe the quality of the rock, whether it were suffi-
t the caisson or not.
ome proportions were enumerated for concrete which
very extravagant. He considered that good concrete
od hard stone properly bound together with good
When there was sufficient cement to bind the sand
than that was waste. In making the mortar, the
lied in the mixing of cement, sufficient mortar to
eing all that was useful. The only justification in
and 2 or 3 was when the cement was liable to be
a current. 1 to 3 with the average sand was just
he knew of no reason requiring more cement, when
p sand of suitable grain was used.
the author spoke of the difficulty of getting fresh
ler was a witness to that, and thought that clause
tion was absurd,—there was no justification for it
t water makes at least as strong concrete, if not
hat made with fresh water. The speaker said that
ests made by himself and others had shown higher
concrete made with salt water than with fresh
as about time that that hoary old clause should no
ntered.
Butler said he would like to call attention to one of
ge 197. A description was there given of the provi-
dency of the walls of the caisson to spread outwardly

Mr. Butler. and he did not believe such a thing ever took place. The ro were usually buckled if stressed at all,—there was absolutely reason why they should go in, and it was a waste of money to p in such large tension members in pneumatic caissons.

There were several other points which he had not had tin to consider, upon which more might be said. He desir to say that, having seen the work on the ground, he wished to be witness to the very excellent manner in which the work was dor and thought it a very creditable feat to all concerned,—the office and men of the Engineering Contract Co., and of the Domini Bridge Company and other men on their behalf, who so successful handled the superstructure.

Mr. Holgate. Mr. Henry Holgate said that the subject of Mr. Taylor's pap was interesting, and the first thing that struck one was the ir mense tidal variation; the Shubenacadie River itself was a cor paratively insignificant stream, but at the point of the crossing the Midland Railway, the river was an arm of the sea and subje to a tide of 32.7 feet. ,

The difficulties of founding piers in the river bed, where tl variation was liable to occur, and where the tidal variation was ways very great, could easily be imagined. The conditions call for the exercise of the greatest of care and good judgment in pla ing. anchoring and sinking the caissons.

The natural conditions were quite severe enough, but were aggr vated by the placing of the piers at right angles to the centre li of the railway and not parallel to the course of the river curren which might have been done to the advantage of this structu He stated that he had measured the speed of an inflowing tide one of the piers and found it to be 16 feet per second, so that t difficulties arising from the location of the piers in respect to t current could readily be appreciated, especially as the current alt nates up and down stream at regular tidal intervals.

The history of the substructure of this bridge conveyed a ve practical lesson to engineers. In the first place, the prelimina work necessary to lead to a proper knowledge of the material up which to found the piers, was not thoroughly done, and the info mation given on the cross-section and plans was not of a concl sive nature. It was therefore a wonder that any contractor wou agree for a lump sum to build the work.

Prior to the signing of the contract, this question had been d cussed, and, while the chief engineer wished the contractors to a sume the correctness of his profile, he would not erase the wo "supposed," so that the contract was executed with this very i portant information unknown to either party. The table given Mr. Taylor, showing the depths found at various piers from t "supposed" to the "actual" level of rock, sufficiently proved the i accuracies in the preliminary information.

remarks relating to the possibilities of litigation, Mr. Holgate.
ors continued in business, were misleading, for the
on the matter being fairly represented to the rail-
hey admitted the conditions and agreed to an arbi-
claims arising from their inaccuracies, so that the
ional work would eventually be paid by the railway

clause covering payment for extra work was inserted
it did not cover (whether intentionally or not) the
s of affairs that arose during the construction, and
antially inoperative.
ing from contract work were, of course, not always
ne above was a very good instance of where all dis-
ve been avoided, had the preliminary information
and from experience, it paid every one concerned
solute facts regarding all points that should be
spending one dollar on construction, and especially
ary in foundation work of all kinds. Also, all con-
ifications should clearly and fairly set out the pro-
ng between the parties, which could only be done
conditions were known to a certainty.
tion of the Shubenacadie Bridge substructure was
traordinary conditions and reflects immense credit
. Thomas, M. Am. S. C. E., who personally superin-
e work, as contractor's engineer, from the beginning,
o his intimate knowledge of pneumatic caisson sink-
general resourcefulness that the work was carried to
npletion.
thought it was also due to Mr. Z. J. Fowler, M. Can.
e here that he was chief engineer of the Midland
at the work was carried out on the plans prepared

ssion following the reading of a paper on the Piers
adie Bridge (the same structure now being discuss-
efore the Western Society of Engineers by Geo. E.
ril 3rd, 1901, General Sooy Smith expressed himself

rs to be most singular, in Mr. Thomas' talk this
hat perhaps invites criticism, (which would not be
ne absence of those who designed the work) in the
an engineering, is the fact that the bridge should
ned as it was, and that there should have been such
edge of the conditions under which these foundations
, and even the material itself upon which they were
well known. The soundings also proved deceptive.

Mr. Holgate. It would certainly appear that that, of all situations, was on which a long span would have been advisable: first, on accoun the extreme difficulty of putting in the piers, and, second, bec of the obstruction of the piers themselves. Great ingenuity called for on the part of those conducting this work as has made evident to us. The greatest difficulties were imposed u them, and it seems to me to have been, to some extent, unnecess if a thorough knowledge of the work had been obtained in the place. If a plan of substructure has been made, adapted to superstructure and adapting itself to the existing conditions, difficulties would have been largely reduced and the final resu seems to me, very much better.

"There is nothing, it seems to me, more important, in preparation for the building of any bridge, than to ascertain the greatest accuracy all the conditions and surroundings, not with regard to the difficulty of doing the work but the good ju ment to be exercised in planning it. Very often economical met can be used when you know perfectly the conditions with which have to deal. Those of us who are gray-headed have learned t things by sad experience, and here is a notable example of a great deal of difficulty growing out of want of knowledge of conditions and want of adaption of the plans to the conditions.

Mr. Kerry. Mr. J. G. G. Kerry stated that he would like to bring up point in regard to a contract such as this one. A cial piece of work was undertaken by contract, freque for a lump sum. The contract was taken by a contracting com who had a full knowledge of this class of work. The enginee staff in charge of the work had probably had no special experi in the particular line of construction that was being underta and had had no opportunity to learn its difficulties. The engin ing staff prepared data to the best of its judgment and ability, the constructing company were perfectly aware of the degree accuracy with which the work had been done. They were taking the entire risk in taking the contract. Upon whom sh the professional onus of proceeding with inaccurate data, r There seems no excuse for a company that would not allow its gineers to secure accurate data, but it also seemed an extraordi thing for a contracting company with the most experienced e neers in the country in its employ, to start to carry out a piec work without first determining the accuracy of the data upon w the plans were based. It would certainly have paid them to g the expense of a preliminary investigation before the work begun.

Mr. Butler Mr. Butler remarked that there was only one fair way to such a contract and that was on the schedule basis.

aid that it was certainly the duty of the railway hat information. They could not expect two, three, of contractors to work out that data. The princi- n getting the contractors to do the work, viz: the rmation. The preliminary information should be Mr. Holgate.

observed that Mr. Kerry had asked why they did rmation after they had signed the contract and be- the work. This he did not consider would have Mr. Walbank.

ted that discussion similar to the present one took ago in connection with some lighthouse work for s Government, and it was suggested that in cases ilty such as the one now under discussion, the con- y should be called upon to tender upon plans of ng. Mr. Kerry.

said that in that case they would have to be paid Io one could be expected to get all the plans out hing for it. Mr. Walbank.

IcPherson said that it seemed to him that Mr. Hol- ly right in saying that the only way was to have ion prepared by the company. Then the contrac- along and they would know from the informa- hem what they had got to tender on, and if they on that information they were, of course, obliged If they considered that further information was ought to say so before taking the contract. Mr. McPherson.

said that there was no doubt that if a contractor he had to carry it out. The Courts had ruled many were there to interpret contracts,—not to make tion under discussion was whether the soundings eeper than shown on the plans. It was stated in f they were required to go deeper (more than 2%) id additional for it. It may be true that they were xed sum of $15.00 per cubic yard of concrete, to but in making out their tender they could add as np sum as they considered necessary to cover the additional depths. However, once the contract was s would interpret that contract. Mr. Walbank.

id that if the information were found to be ma- t, it was doubtful whether the courts would hold responsible. Mr. Kerry.

observed, in regard to the 2%, it was apparently as- additional work was of the same nature and in the s the work shown on the plans, but, as a fact, the lower level was entirely different and more difficult Mr. Holgate.

Mr. Holgate. to handle. Would not this fact affect the carrying out of such arrangement?

Mr. Kerry. Mr. Kerry stated that in reading this paper to-night, he had had time to grasp the whole sense of the different points, bu appeared to him in taking this contract, the fact that the infor tion was incorrect and could not be relied upon must have b perfectly known to those who understood this class of construct and no one more clearly than the engineers of the construct company.

He said that he was not sure, but thought this was a para case to that of the Cornwall Bridge, which failed from exactly same causes, and for which the contracting company was held sponsible.

Mr. Walbank. Mr. Walbank observed that if they took the contract they w be responsible for it, even if the information were not correc once they signed a contract they had to carry it out.

Mr. Kerry. Mr. Kerry said that his argument was that immediately a they took the contract, it would have been good practice on the of the contractors to verify the data furnished to them before ceeding with the construction.

Mr. Walbank. Mr. Walbank said that it might have been good practice to certain if the information given was correct, and, if not, refus proceed.

Mr. Johnson. Mr. Johnson stated that, as a matter of fact, he did not t if the contractors had known in advance that the plans were in rect, it would have changed matters greatly, except that they w have known better what to provide for and what outfit and terial to procure.

Mr. Butler. Mr. Butler said he did not think there was ever a trial in nection with the Cornwall Bridge. He understood that the s tion was that all the parties in interest became insolvent an did not, therefore, come to a trial at all. The New York Ottawa railway company went in the receiver's hands, and the struction company became insolvent and no adjudication was

Mr. Walbank. Mr. Walbank stated that he had heard of a case which occu some years ago, where the contracting firm undertook the erec of a bridge,—he understood it was for the C.P.R. He believed protested after taking the contract, against going ahead with work and they were told that the plans were standard and w have to be carried out. They entered a notarial protest and on with the work. The whole 54 spans were afterwards bl down, and they were told by the railway company that they w have to make it good. They secured legal advice, and one la told them they would not have to make it good, but another la told them that, as they had signed a contract, they were respo ble and would have to make good the damage.

GENERAL SECTION.

An illustrated address on "The Use of Rock and
ge and Reservoir Construction" was given by Mr.
of Philadelphia.

Meeting was held April 14, 1904, Mr. McLea Wal-
Council, in the chair. Messrs. J. W. Heckman, J.
M. Nelson, H. R. Lordly, W. J. Sproule, and J.
g been appointed scrutineers of the ballot for the
bers, declared the following elected:—

ASSOCIATE MEMBERS.

..	T. E. LAMB.
TON.	L. N. JENSSEN.
AE.	J. O. MONTREUIL.
LE.	H. J. D. ROSS.

K. WEATHERBE.

FROM CLASS OF ASSOCIATE MEMBER TO THAT OF MEMBER.

J. G. G. KERRY.

FROM CLASS OF STUDENT TO THAT OF ASSOCIATE MEMBER.

CORRIVEAU.	C. S. GZOWSKI.
LIN.	J. H. LARMONTH.
H.	J. A. WALLS.

ASSOCIATES.

AUCHON.	R. E. T. PRINGLE.
.	

STUDENTS.

ER.	J. H. BURD.
NDIGE.	F. F. CLARK.
ASSCO.	P. A. G. DEY.
ABBADIE.	M. J. MURPHY.
	A. G. MCAVITY.

J. B. Harvey.
W. D. Lawrence.
A. McLean.
F. G. McPherson.
Frank Peden.
W. Redpath.
A. G. Tapley.
G. B. Webster.

E. T. J. Brandon.
J. F. Mack.
T. H. Hogg.
L. E. H. Grant.
H. L. Price.
M. V. Sauer.
S. M. Thorne.
J. S. M. Wynn.

VOL. XVIII. 1904. PART II.

TRANSACTIONS

OF THE

Canadian Society of Civil Engineers

OCTOBER TO DECEMBER

[illegible]

[illegible]

TRANSACTIONS

of the

Canadian Society of Civil Engineers

OCTOBER TO DECEMBER.

1904.

Montreal:

PRINTED FOR THE SOCIETY

AT THE WITNESS PRINTING OFFICE,

1905.

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Engineering approximation

INSTRUCTIONS FOR PREPARING PAPERS, ETC.

In writing papers, or discussions on papers, the use of the first person should be avoided.

They should be legibly written on foolscap paper, on one side only, with a margin on the left side.

Illustrations, when necessary, should be drawn on the dull side of tracing linen to as small a scale as is consistent with distinctness. They should not be more than ten inches in height and *in no case* should any one figure exceed this height. Black ink only should be used, and all lines, lettering, etc., must be clear and distinct.

When necessary to illustrate a paper for reading, diagrams must be furnished. These must be bold, distinct and clearly visible in detail for a distance of thirty feet.

Papers which have been read before other Societies, or have been published, cannot be read at meetings of this Society.

All communications must be forwarded to the Secretary of the Society from whom any further information may be obtained.

The attention of Members is called to By-Laws 46 and 47.

The Society will not hold itself responsible for any statement or opinions which may be advanced in the following pages.

"The papers shall be the property of the Society, and no publicatio of any papers or discussion shall be made except by the Society or wit permission of Council."—By-Law No. 47.

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GENERAL SECTION.

President—D. MacPherson.
Vice-President—C. H. Keefer.

ı session opened with a meeting of the General ırsday, October 20, 1904, Mr. D. A. MacPherson in following paper was read by the author:—

MENTS ON LOSS OF HEAT FROM IRON PIPES.

y R. W. Leonard, M. Can. Soc. C. E.

of obtaining reliable data in convenient form re- s of heat from warm water through the walls of f differing dimensions, when exposed to cold air or fering conditions, led the writer to make a few ex- g the past winter, which was favourable for such results of these experiments may be of interest to of the society.

ut welded steam pipe. Black—somewhat rusty.

liam.	1.048″
"	1.315″
ss	0.134″
	4.25′ contains 1. 581 lbs. water.
l surface	1.463 sq. ft.

ut welded steam pipe. Black.

liam.	2.067″
"	2.375″
ss	0.154″
	3.54′ contains 5 lbs. water.
l surface	2.20 sq. ft.

iron pipe. Gauge 28.

er	2″
ss	0.016″
	35.3″ contains 4 lbs. water.
l surface	1.54 sq. ft.

D.

2″ Bright tin pipe. Gauge 26.

Diameter	2″
Thickness	0.018″
Length	35.3″ contains 4 lbs. water.
External surface	1.54 sq. ft.

E.

2″ Lap-welded charcoal iron boiler tube. Black.

Inside diam	1.810″
Outside "	2.000″
Thickness	0.095″
Length	41″ contains 3.805 lbs. water.
External surface	1.784 sq. ft.

G.

1″ Standard but welded stem pipe. Galvanized.

Inside diam	1.048″
Outside "	1.315″
Length	0.134″
Thickness	4.25 contains 1.58 lbs. water.
External surface	1.463 sq. ft.

A. and G. were filled with warm water and exposed under a
to a temperature of from 16° to 20° F., and the rate of coolin
illustrated in accompanying diagram (Fig. 1).

A. B. C. and E. were filled with warm water and exposed in
open air on a very still day (no perceptible wind blowing) t
temperature of from 7° to 10°F. The rate of cooling is illustr
in Fig. 2, which also illustrates the rate of cooling of pipe B.,
posed to a wind at low temperature.

A. B. C. D. E., were filled with warm water and submerge
still water under the ice, and the experiment was repeated i
current of water at 32° flowing at 1½ feet, per sec., and the res
are shewn in figs. 3 to 7. Fig. 8 shows the rate of cooling in (
the current. In all cases the pipes were exposed in a vertical p
tion sheltered from the sun.

All of the diagrams show irregularities which may be attrib
to inaccuracies in reading the fine divisions on the thermometer
to possible irregularity in circulation of the warm water w
cooling in the pipes. Apart from these irregularities the diffe
ces between figures 1 and 2 are interesting.

In the following table the writer compares the loss in B. T.
per sq. ft., of external surface from the different pipes under
differing conditions.

COMPARISON OF TRANSMISSION FROM VARIOUS TUBES.

Description.	Thickness. Inches.	Ext. Surface Sq. Ft	Contents. lbs. water.	Loss in B. T. U.'s per sq. ft. per hour.	Temperatures Fahrenheit.
B. 2" Welded Steam Pipe—Black	0.154	2.20	5.00	124.0	From 142 " 32 in still air at temp. 7° to 10° F.
B. 2" " " " "	"	"	"	112.6	" 126 " 32 " " " " " 7° to 10° F.
B. 2" " " " "	"	"	"	217.3	" 126 " 32 " wind 8" to 12" per sec. 5° to 7° F.
B. 2" " " " "	"	"	"	309	" 126 " 32 " still water temp. 32°.
B. 2" " " " "	"	"	"	269	" 116 " 32 " " " " 32°.
B. 2" " " " "	"	"	"	849	" 116 " 32 " current of 1½" per sec. temp. 32°.
E. 2" Lap Welded Boiler Tube -	0.095	1.784	3.805	136.7	" 142 " 32 " still air temp. 7° to 10°.
E. 2" " " " "	"	"	"	385	" 142 " 32 " still water temp. 32°.
E. 2" " " " "	"	"	"	1005	" 142 " 32 " current of 1½" per sec. temp. 32°.
A. 1" Welded Steam Pipe—Black	0.134	1.463	1.58	115.0	" 142 " 32 " still air temp. 8° to 10° F.
A. 1" " " " "	"	"	"	297	" 142 " 32 " " water temp. 32°.
A. 1" " " " "	"	"	"	982	" 142 " 32 " current of 1½" per sec. temp. 32°.
G. 1" " " " Galvan.	"	"	"	950	" 142 " 32 " " " " " " " 32°.
C. 2" Gal. Iron Pipe - - - - -	0.016	1.54	4.00	129.0	" 142 " 32 " still air " " " " " 7° to 10°.
C. 2" " " " - - - - - -	"	"	"	451	" 142 " 32 " still water temp. 32°.
C. 2" " " " - - - - - -	"	"	"	1008	" 142 " 32 " current of 1½" per sec. temp. 32°.
D. 2" Tinned Iron Pipe - - - -	0.018	"	"	470	" 142 " 32 " still water temp. 32°.
D. 2" " " " - - - -	"	"	"	1224	" 142 " 32 " current of 1½" per sec. temp. 32°.

From the above data it is possible to calculate approximately amount of warm water it is necessary to pump through the holl bars of a rack protecting water wheels in order to prevent t accumulation of frazil thereon, as it is necessary to raise t temperature of such bars but a fraction of a degree to accompl this end.

The curves indicate that water slightly warmed loses its h much less rapidly than hot water when exposed in a tube to a c rent of ice cold water.

To illustrate the practicability of this idea the example of of the units in the extension of the Hamilton Cataract Pow Light & Traction Co.'s plant near St. Catharines may be taken.

The data are as follows :—

Head of water, 267 feet.

Capacity of turbine 245 c. ft., per sec., delivered through s penstock 6′ 6″ diameter.

Power of each turbine 6,000 H. P.

Rack is 18′ 6″ wide with length of 16 ft. submerged at ordin water level.

Thin iron pipe can be flattened to serve as bars spaced as des and connected top and bottom with headers to form sections of rack suitable for the circulation of warm water under pressure f a pump.

The water area through the rack may be arranged to allow current of 1½ feet per second, thus corresponding with the con tions existing in the experiments quoted above.

Now assume the water for warming the rack to be heated to and returned to the heater at a temperature of 35° after being posed to a current of 1½ feet per sec., in ice cold water. This of 31° takes place in 4 min., from a 1″ boiler tube from 1.6 lbs. water = 50 B. T. U.'s from a surface of 1.463 sq. ft., or, say B. T. U.'s per sq. ft., in 4 min. or 510 B. T. U.'s from 1 sq. ft. hour.

The total pipe surface submerged in such a rack equals 6 sq. ft., therefore the transmission of heat from whole rack hour equals 354,603 B. T. U.'s.

Assume a boiler evaporating 9 lbs., water from and at 212 per lb., coal or yielding 8,694, B. T. U.'s per lb., coal (latent 966 B. T. U.'s.)

Therefore the coal required per hour to warm water equ 41 lbs., requiring a grate area of 5 sq. ft., (with 8 lbs., coal bu per hour per sq. ft. grate area) or a boiler of 15 H. P.

The quantity of water to be heated may be arrived at as follo 1.6 lbs., water loses 31 temp., in 4 min., or at the rate of B. T. U.'s per hour.

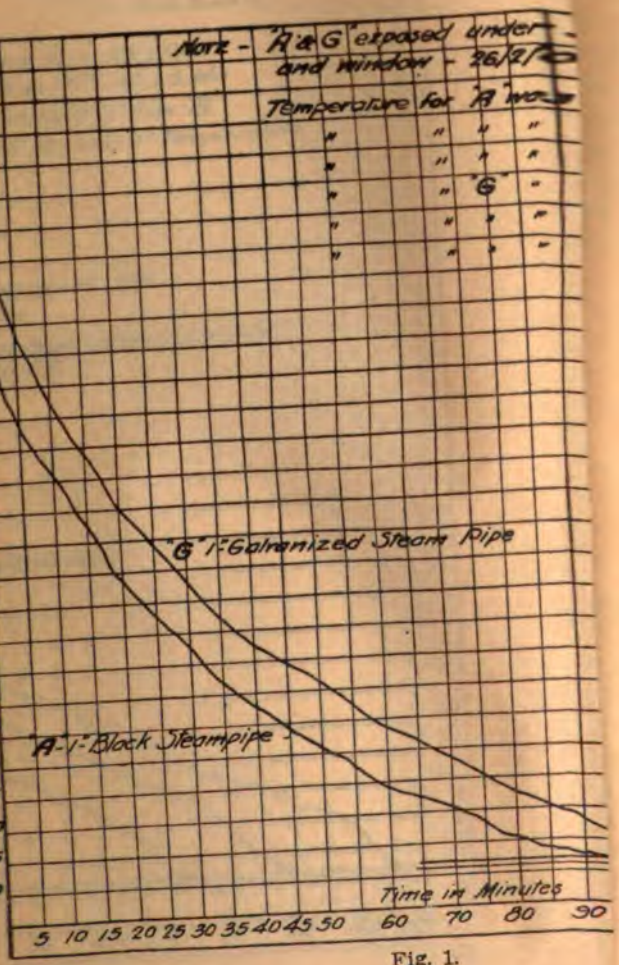

Note - "A" & "G" exposed under -
and Window - 26/9/
Temperature for "A" was
" " " "
" " " "
" " "G" "
" " " "
" " " "
"G" 1"-Galvanized Steam Pipe
"A"-1"-Black Steampipe
Time in Minutes
5 10 15 20 25 30 35 40 45 50 60 70 80 90

Fig. 1.

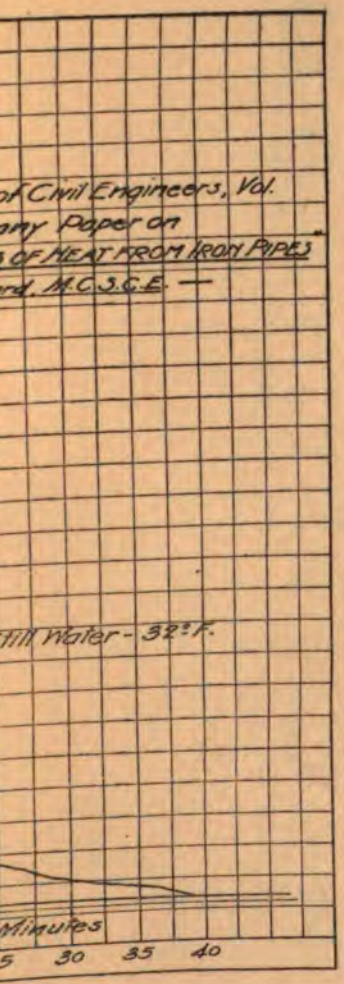

of Civil Engineers, Vol.
any Paper on
s OF HEAT FROM IRON PIPES"
rd. M.C.S.C.E. —
till Water - 32° F.
Minutes
5 30 35 40

Fig. 5.

rack (as above) 354,603 B. T. U.'s, requiring a
bs., per hour or 122 gals., or little over two

difficulties caused by the freezing of the water
ack when the heating system is not being used
to use some fluid which freezes only at a very

that the same principle can be economically
accumulation of frazil on other hydraulic
water wheel casings, etc.
nt to the reader that with a lower head of
onding increased volume, the circulation of a
r quantity of warm water would be necessary
e purpose desired, and there comes a point at
tained is not worth the expenditure of fuel
rpose.

DISCUSSION.

Mr. Rhys-Roberts.

Mr. E. A. Rhys-Roberts wanted to know whether such fla iron pipes had ever been used in actual practice.

Mr. Ross.

Mr. R. A. Ross said it seemed to him that ordinarily the had little enough space between them, and the pipes, even i tened, would occupy considerably more space than if ordinar were used. The question of the pipes freezing up and bu would be something which would have to be carefully consi

Mr. Durley.

Prof. R. J. Durley said he had had considerable experie making tests on the loss of heat from iron pipes, and had fo by no means easy to obtain figures which were at all accordan this case, he considered the tests had been made on compara short lengths of pipe, containing rather a small quantity of and the scale upon which the experiments were made, rather which would, of course, make it more difficult to obtain re results.

In regard to the experiments which were made with the exposed to the air, the author simply stated that "the pipes exposed to still air." It had been the speaker's experience th making such experiments, the air surrounding the pipes was means still. The fact that the pipes were hot, of course, cau current of air to pass over them. The figures would have more valuable if the author had given details showing how actual circulation of the air there was. In reference to the qu of warming the rack bars, Mr. Leonard did not seem to have templated the possibility of the rack bars themselves bec coated with ice. He would like to ask some of the members had had experience with such racks, whether the racks them did not become coated with ice. He could not see how the perature of the metal in the pipes themselves could be raised materially until all the ice was melted.

Mr. Kerry.

Prof. J. G. Kerry said the evident intention of the devic to prevent the freezing of ice to the rack bars at all, by h them before any freezing took place. The characteristic of was that it would not adhere to any surface if the tempe were at all above 32 deg. Fah.

He would like to ask of the members who had had expe in connection with such plants as to the practical working device. If the water came down full of frazil, the device assured that the frazil would pass through the racks, as no pro was made for the breaking up of the frazil by heat. Woul frazil pass through the turbines after it had passed throug

ge in the turbines? It would be about as frazil clog in the turbines as in the racks. was taken up to a small extent at the time s address to the Society on "Ice Formation The speaker remembered suggesting to him, bility of removing frazil from the water to and kindred structures by the direct appli- ussing the best way to estimate the number n any particular case. It was evident that commercially much more promising with a DeCew Falls, where there was a very large ely small quantity of water, than in one s were reversed. On account of the very coal, and the low efficiency of the ordinary sible that a plant which utilized its boiler l and in keeping its water wheels running, be more efficient than one which used the for an auxiliary steam plant. The laws of nveyance were sufficiently coupled to make l for special physical investigation. Mr. Kerry.

d he believed there had been considerable vith ice forming on the wheel itself, and There was also the chance of frazil form- elves, because the temperature of the upper lder than that of the water. This, of course, ilding a house or shed over the racks. This ful as a shelter for the men when they were Mr. Ross.

ll asked whether, in the designing of these ing the racks, any other section of hollow ered. It seemed to him that if the object t the ice should pass through, a flat oval purpose very well. He had not noticed any flattened round pipes, to which the author his experiments. The speaker could not s made like a heater would not serve the re, as in the special case of Mr. Leonard's be practically free from blows from drifting Mr. Blackwell.

bank said that personally he did not have the proposed arrangement for the average ids six or seven years' experience had been t time only twice was there any difficulty the racks. In fact, only once actually from on this occurred before the head race was er, it was not frazil, but ice frozen solid to Mr. Walbank.

Mr. Walbank the racks, which were of iron and projected several feet ab water level. To obviate this difficulty at the time, the tops racks were covered with snow to prevent the cold being down them. The plant in question had, however, during t two years been operated without racks and no trouble ha experienced.

Quite possibly the plan of heating the racks might be fully applied to very small plants employing a high head an little water, but even then it was doubtful whether it wou paying proposition to heat the racks, and it would be po out of the question in plants like the one cited above.

Mr. Smith. Mr. C. B. Smith said that Mr. Leonard had raised important question by his interesting experiments on loss from pipes filled with hot water and subject to flowing cold and to give the matter a still further practical application i be necessary to take his results and develop them to a leg conclusion.

The 6,000 H. P. wheel instanced required 245 cu. feet p which was 55,125,000 lbs. of water per hour, and Mr. Leona stated that a 15 H. P. boiler would generate 354,603 B. T. hour, which would only affect the temperature of the water through the rack 1/160 degrees Fahr., or by the expendi 2,400 H. P. the temperature could be raised 1 degree Fah when it was considered that the latent heat of ice was 1 B. T. U.s, and that the heating effect was only required w water had a large amount of frazil or anchor ice in suspen was evident that any reasonable expenditure would only infinitesimal effect. Another related conclusion was that closed forebay room would afford a comfortable opportun men to keep racks raked clean in winter time, but would no any appreciable advantage in inducing the frazil ice to pass the ice racks without adhering to them.

Mr. Leonard. Mr. Leonard replied to Mr. Blackwell that flattened iron pi not actually been used for such purposes, but he saw no why thin circular pipes such as boiler tubes should not be fl for the purpose or made of oval section. More space fo would have to be provided than in the case of flat bars on of increased thickness of such oval bars. To prevent fre special fluid might be used, or the tubular rack entirely sub

As pointed out by Mr. Durley, the scale on which the ments were made was small, the apparatus rather crude, results consequently not as accurate as might be desired; experiments were carried out under working conditions, a nish some reliable information on a subject which had not the attention it deserved.

ith's discussion was interesting, as it showed that Mr. Leonard.
not sufficiently emphasize the fact that the object
application was to present the chilling of the rack
to allow an accumulation of frazil, and not to
the minutest fraction of a degree or to melt the
ut by Mr. Kerry. If the amount of heat required
a small amount of frazil from the water were
mpracticability became at once apparent, except
ts running under extremely high heads.
plants it was the custom to remove the racks or
for the winter, or when frazil was forming, in
heels were run without protection, and on account
eltered position would frequently continue to run,
gh them that would make a solid dam of the pro-
n place. The same system of heating portions of
might be found desirable.

ELECTRICAL SECTION.

President—R. B. Owens.
Vice-President—W. McLea Walbank.

At the first meeting of this section on Thursday, Nove 3rd, 1904, the following paper was read:—

PAPER NO. 211.

THE DESIGN, CONSTRUCTION AND TESTING OF CORE TRANSFORMERS.

By A. E. Foreman, S. Can. Soc. C. E.

One of the principal reasons that continuous current rapidly giving place to alternating current, is the ease with the latter may be transformed from low voltage and large rents to high voltage and correspondingly small current, allowing a great saving in copper, where the current has to be ried any distance.

The device or apparatus used to bring about this chan called a "transformer," or more correctly, a "static transfor to distinguish it from a "rotary transformer" which has m parts.

Static transformers may be divided roughly into two ge classes, namely, "shell transformers" and "core transformers. the former the iron is built up around the windings, while i latter the coils are wound on the core as a centre.

The core transformer has a number of advantages ove shell type, and on that account is rapidly replacing it. The of the former is simpler and more easily constructed, and the face between the primary and secondary, being cylindrical in line, makes it possible to provide the simplest and most effe form of insulation shield between the high and low potential

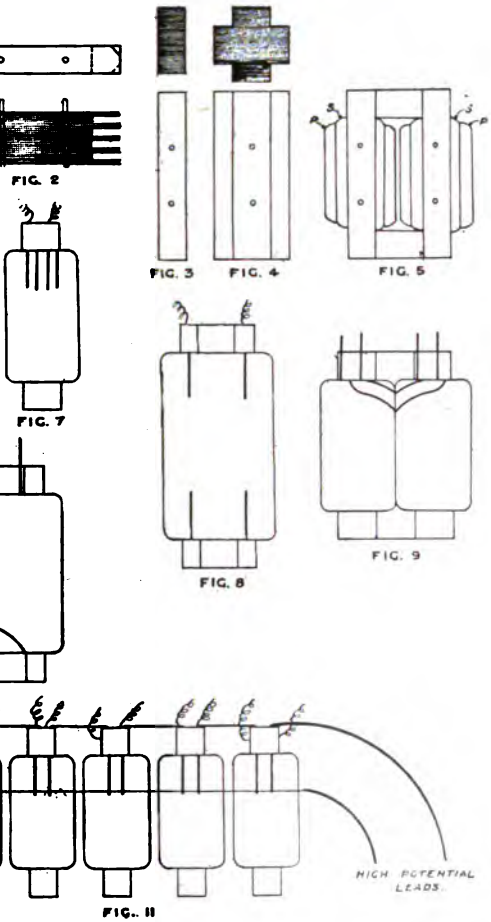
It has become a very efficient piece of apparatus, large t formers having an efficiency as high as 98%. Its advantages a D.C. converter are quite obvious, when it is remembered tha latter, besides costing much more and needing constant atte seldom has an efficiency of more than 90%.

The transformer consists of a laminated iron core, upon two separate and distinct coils are wound, half of each coil on leg. Plate 1, Fig. 5. When an alternating current is suppli one of these coils, it produces rapid reversals of magnetism i iron, and these in turn induce an alternating electromotive in the other coil.

h the alternating current is supplied, is called the coil which delivers a current is called the

has more turns than the other. If the primary nber of turns, a current of lower voltage is

Plate 1.



secondary. This is called a "step-down trans- nary has the less number of turns, the induced of the secondary is greater than that applied s is called a "step-up transformer."

There are four essential points in transformer design, nar high insulation, low temperature rise, good regulation, and core loss or high efficiency.

High insulation is not only important to prevent free burnouts and interruptions in the service, but is doubly impo as a means of safety to those handling the secondary lines.

Transformers should never be subjected to high temperat as the insulation will become charred and brittle, this deter tion resulting in the transformer being burned out.

For all temperatures over 85 degrees C. the iron has been to gradually age, causing an increase in core loss. This pl menon takes place more rapidly if the iron is subject to a pres

For outdoor work, transformers are placed in cast iron and submerged in oil. This has a twofold advantage. The a good insulator, and helps to strengthen any weak spots i insulation, and it conducts the heat to the other surface, it is dissipated. This has a very material effect on the ri temperature. Transformer oil has been found to gradually its efficiency as an insulating medium, when the temperature above 70 degrees C., the oil being broken up, and carbon and conducting substances deposited. For the reasons stated a the rise of temperature above that of the surrounding air sl never exceed 50 degrees C., some authorities even placing it degrees.

In transformers the "regulation" is the ratio of the rise c secondary terminal voltage from full load to no load (the pri voltage remaining a constant) to the secondary terminal vo at no load.

This falling off in secondary voltage is due to two ca firstly, magnetic leakage, and secondly, the resistance of primary and secondary coils.

In this type the falling off due to magnetic leakage wi quite small, because the coils are wound the one over the c In well designed transformers the falling off in secondary vo should not vary more than from 1% to 3%, depending on the put.

On the regulation depends the character of the service may be rendered; for it determines the variation of volta which the lights will be subjected, and inasmuch as the given by a lamp, and its commercial life, vary very rapidly the voltage, the importance of fine regulation in givi g good mination service, and insuring durability of lamps is quite obv

The "efficiency" of a transformer is the ratio of the power put to the power input. There are always losses in a transfo due to three causes, hysteresis loss, eddy current l[illegible] and c[illegible] losses, so that the efficiency of a transformer cannot be 100%.

s due to hysteresis depends upon the quality the core, as well as upon the maximum worked. The magnetic flux is nearly con- that the hysteresis loss will be about the l is dissipated in the form of heat. Stein- g formula for the hysteresis loss in watts:—

$$W_h = a\,V\,f\,B^{1.6}$$

depending upon the quality of iron.
iron in the core.
and
flux density.

urrents in the iron also causes heat losses, ished to a great extent by laminating the being to break up the paths in which the reducing their volume. The following equa- y current loss in watts:—

$$W_e = b\,V\,L^2\,I^2\,B^2$$

in the core.
lternations.
ux density.
he laminae.

depend on the resistance of the wire in the coils, and on the square of the current If I_p and I_s represent the currents flowing condary coils, and R_s and R_p the resistance ely, then

$$W_c = R_p\,I_p^2 + R_s\,I_s^2$$

s to be run continuously, the iron losses to the copper losses, but if a transformer is of the day only, five hours generally being or lighting circuits, then an allowance must ile the copper losses take place only when ded the iron losses go on continuously, as ally maintained all day. In this case the ours should about equal the iron losses for

uld be designed so that it will do the work rrent with the least possible cost. To do not only be high at full load, but it must ide range of load; it being found that trans- ht load, about as much as on full load.

The efficiency cannot be increased beyond a certain a without greatly increasing the weight and cost, and a tra mer may be said to be well designed when it gives the high day efficiency consistent with an economical distribution o and copper.

PLATE 2

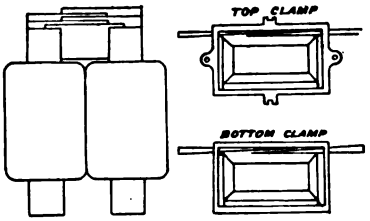


FIG. 1 FIG. 2 FIG. 3

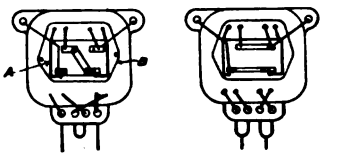


FIG. 4 FIG 5

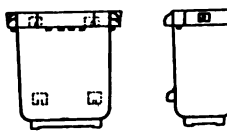


FIG. 6

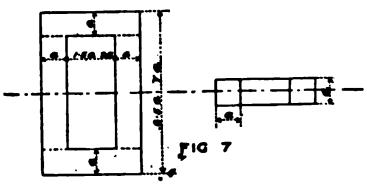


FIG 7

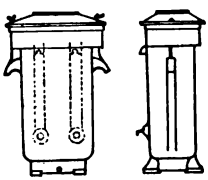


FIG. 8

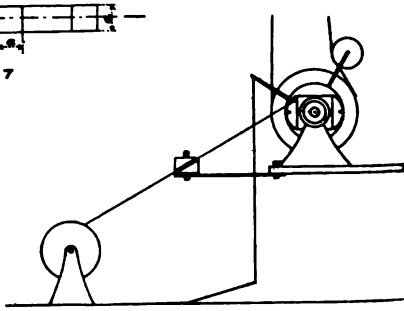


FIG 9

In starting to design a transformer the following quantiti known:—

Useful secondary output in watts.

Frequency of the system at which the transformer is operated.

ell designed transformers of different capa-
by experiment, and can be gotten from
uired secondary output and the efficiency,
be found. The difference between this and
sses for the stated efficiency.
ch the losses are divided between the iron
on the use to which the transformer is to
nd as stated above. Having decided upon
iron losses are equal to the sum of the
rrent losses; the required volume of iron in
rom the equation.

$= a V f B^{1.6} + b V f^2 L^2 B^2$

e system being decided upon, the maximum
ickness of the discs for that frequency, can
tables. The thickness, L, usually varies

sions in Plate 2, Fig. 7, are found in good
tory results. "a" being found, we know the
of the iron core, and therefore the total
ng it.

$E = 4.44\ N\ T^{p}\ n\ 10^{-8}$
primary voltage.
cycles.
ber of lines threading the circuit.
f turns on the primary.
er of turns on the primary coil can be
ns go on each leg; and as the length of
is known, namely, 4.5 a—5a, the number of
d.
at the number of turns on the secondary is
on the primary, as the secondary voltage
ge, so that the number of secondary turns
number of layers on each leg can be found
s the number in the primary.
peres that will flow in the secondary at full
tts output divided by the secondary voltage.
the number of circular mm. per ampere
verheating. From these two quantities, the
for the secondary coils can be found. It
ingle wire, or of a number of wires in mul-
ton insulation, so long as it contains the

required number of circular mm. The size of the primary may be found in the same way.

Now the diameter of the core is known; the diameter primary and secondary wires plus their cotton insulation, ar number of layers in each are also known. From these quar the mean diameter of each coil, and therefore the total leng wire in each leg may be found.

Space must be allowed for good insulation between the dary and core, between the primary and secondary, and be each layer of both the primary and the secondary, and shou taken into account in finding the mean diameter of the tur each coil.

The difference of potential between two layers which the lation has to withstand can easily be calculated. If, for exa the primary voltage of a transformer is 1,040 to 2,080, the dr potential between the terminals on one leg is always 1,040 because the two legs are placed in series on a 2,080 volt line the number of layers on one leg be 8, then the drop of pot along one layer will be 130 volts. Thus the difference of pot between the beginning of one layer and the end of the nex be 260 volts. The insulation must be able to withstand a greater voltage in case of an emergency. A factor of saf about five is generally allowed.

All the requirements necessary for the production of a former have been found, and it remains to describe how the tical construction is carried out.

The core is built up of thin rectangular iron strips, whic interleaved at the corners so as to practically do away with in the magnetic circuit.

The discs are cut into the required shape and size in a p ing machine, and then passed between a pair of steel rollers move the burr formed by punching. Wooden pegs pass th the "piling holes" shown in Plate 1, Fig. 1, to keep the di place, and the bevelled corner is to facilitate the assembling legs.

The discs are japanned for insulation, this also being do machinery. Plate 3 shows the machine in plan and elevator. discs are passed between two pairs of rollers, A, the lower t which rotate in air-drying japan at such a depth that the is caused to pass over all four. The distance of the upper r from the lower ones can be regulated so as to allow the req amount of japan to remain on the discs. They then pass on carrier which conveys them between blasts of hot air, and arrive at the other end ready for piling.

In designing the transformer the "volume" of iron was but as laminated cores are used in the construction, table

iven to the workmen, specifying the "weight" of g, the size of discs, and the height to which they for the different sized transformers. The legs must n weight, as nearly as possible, piled to the stated

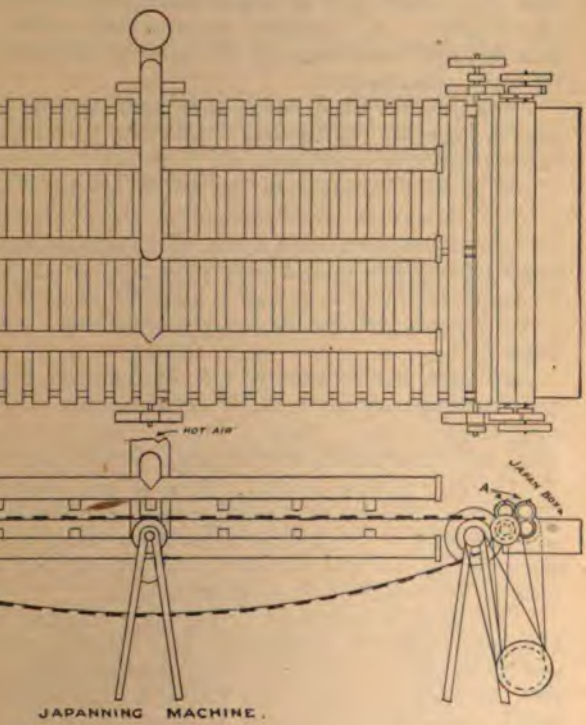


Plate 3.

ng table gives the requirements for a few trans-

e of Discs.		Height of Core.		No. of Assemblers.		Wt. of leg in lbs	
	125 cycles	60 v.	125 v.	60 v.	125 v.	60 v.	125 v
	$1\frac{3}{8}'' \times 7\frac{1}{2}''$	$3\frac{1}{2}''$	$2\frac{3}{4}''$	2	2	$7\frac{1}{2}$	$5\frac{1}{2}$
	$1\frac{1}{2}'' \times 8\frac{1}{2}''$	$4\frac{1}{2}$	$3\frac{1}{2}''$	1	2	20	$7\frac{1}{2}$
	$1\frac{5}{8}'' \times 10\frac{1}{8}''$	$5\frac{1}{8}''$	$4\frac{1}{2}''$	3	2	$28\frac{1}{4}$	20
	$1\frac{3}{4}'' \times 11\frac{3}{4}''$		$5\frac{1}{8}''$	3			$28\frac{1}{4}$

transformers are made for either a 60 or an 125 As a transformer would have greater core loss with

125 cycles than with 60, other things being equal, the loss is di nished by putting less iron in the former for a given capacity transformer.

It will be seen from the tables that a given sized disc does both 60 and 125 cycle transformers; the difference being that i used in a transformer of larger capacity for 125 cycles, than i for 60 cycles. For example, the disc used in the core of a 4 watt 60 cycle transformer is also used in the core of a 6,000 v 125 cycle transformer.

The discs are piled two or three to a layer on iron rods, wh pass through the "piling holes," alternate layers having the lon ends in opposite directions.

Of those protruding to the right, alternate layers have bevelled corners on opposite sides, so also for those protrudin the left, as shown on Plate 1, Fig. 2. This is continued until the quired weight has been added, when the core is pressed down the given height in a vice, and tied with cambric tape. The i rods are then replaced by wooden pegs, which keep the discs place.

125 cycle transformers of 6 K. W. capacity and under, and cycle transformers of 7½ K. W. capacity and under, have rect gular shaped cores. Plate 1, Fig. 3. For all sizes larger t those mentioned above, star shaped cores are used. Plate 1, Fi

The core is now placed in a lathe and wound. The ends the core fit into wooden frames, which are centered on the la and turn with it. The ends of the cores fitting into the wood left unwound, for the purpose of assembling, and are of a len equal to the width of an assembling disc.

The lathe is connected to the main shafting by a loose l A tension pulley is so connected that it can be forced against belt by means of a foot rest, and thus tighten the belt, so as give any required speed. The reel of wire is placed on an axle that the wire will unwind easily as it passes into the core.

The wire is passed between two wooden blocks, which serve a tension. The blocks are lined with leatheroid, so as not to jure the insulation of the wire, and are attached to one end o board, the other end of which is pivoted to the bench, in order allow the block to be moved back and forward as the wire being wound on the core. An automatic counter attached to lathe indicates the number of turns that have been wound. Plate 2, Fig. 9.

On the pressed core is wound one layer of (.007") cotton ta half lap, and saturated with a compound called "enshellac"; pie of 1-32" horn fibre, 1" square being placed over the ends of wooden pins. Then along each corner are placed three thickne

r tape, 1″ wide, extending beyond the layers
er the ends of the secondary coils.
one wrapping of (.012″) treated cambric, the
be turned over, and tied down upon the top
when wound. Corner pieces of 1-32″ horn
l angles. The insulation is capable of with-

l is now added, care being taken that the

supplied to the men stating the size of
s and number of turns on each leg, in the
for the different sized transformers. The
he dimensions of a few transformers for an

ts Primary.		52—104 Volts Secondary		
ls Size of wire	Turns	Layers	Coils	Size of Wire
25 B & S	108	3	2	10 B & S
23 B & S	104	4	2	·183″ × ·077″
·028″	75	4	2	·270″ × ·090″
·040″	72	2	4	·160″ × ·110″
13 B.W.G.	30	1	4	2(·500″ × ·095″)

econdary is insulated from the other. First
0″ white rubber tape 1″ wide are laid along
t secondary layer, and over them is placed
ned duck, upon which the second layer is
ng layer is insulated from the preceding
Light duck (.010″) is used on transformers
ity, and heavy duck (.020″) on transformers
e ends of the treated cambric under the
folded over and tied down, two wrappings
le of resisting 1,000 volts are applied and
yer of (.007″) cotton tape, half lap. Each
sists of two pieces of (.010″) varnished red
ayer of (.010″) mica. Three thicknesses of
en wrapped over this, the whole being
g 10,000 volts.
w added with the following insulation be-
ness of double oiled white paper (.004″) for
; one thickness of oiled red paper (.010″)
atts; and one thickness of (.010″. red paper,
ickness of (.012″) treated cambric on each
00 watts. The first and last turns of each
h one thickness of (.012″) treated cambric
ver the wire. Each layer is thoroughly
ac as completed.

After the ends of the treated cambric under the primary h been turned over and tied down upon the top of the coil, wrapping of (.010") cotton cloth is applied and saturated v enamelic. Over this are placed two shields, each consisting of thicknesses of (.010") paper and one of (.012") treated cam placed on opposite sides of the coils, and held there by a l of (.007") cotton tape, half lap.

A ground shield is added, if called for by the specificati It consists of a metal shield placed between the primary secondary, and insulated from the former by the 10,000 volt sulation, and from the latter by the 2,500 volt insulation. connected to the ground, and is added to the transformer means of safety, so that when a breakdown occurs in the ins tion between the primary and secondary, the former is groun and the latter protected from the high voltage.

The primary always consists of one coil on each leg, fo sizes of transformers. The coil is sometimes wound in two p each part being wound from the end to the middle of the and the beginning of one part soldered to the end of the othe fore the last insulation is put on. The primary terminals always brought out at the top of the transformer.

The secondary is wound in different ways. For small tr formers up to 2.5 K. W., the secondary consists of a single on each leg. Plate 1, Fig. 6. For 2.5 K. W. transformers over, the secondary consists of two separate windings on each In sizes ranging from 2.5 to 5 K. W., all the terminals are bro out at the top. Plate 1, Fig. 7. While on those of larger capa the winding is begun at the top, and the ends brought out at bottom. Plate 1, Fig. 8.

The legs are assembled together as shown in Plate 2, Fi by a certain number of layers of japanned discs, two or three being used to a layer, as specified in the previous table.

The discs are insulated from the coils by a layer of leatheroid, and an insulation built up of three layers of varni red paper, each separated from the other by a layer of mica. mica paper insulation is also placed between the legs.

After receiving a good coating of shellac, the transfor are sent to the ovens, and are baked for three days (72 hours a temperature of 170° C.

Cast iron clamps are now fixed on the ends of the tran mers to hold the two legs and the assembling discs firmly in p In the smaller transformers they are insulated from the magnetically, by means of wooden strips which line three of inner sides of the clamps, and by wedges of the same mat which are forced into the fourth side to hold the clamps fi in position. Plate 2, Fig. 2. For the larger sizes the clamps

nd are fastened in place by means of two
ugh the castings, as shown in Plate 2, Fig.
l from the core by a leatheroid washer.
l 10 show the internal connections of trans-
o coils on each leg.
cables are soldered to the remaining four
ndary; the ends of the cables having been
eep them from unwinding.
to be connected in such a way that it can
n parallel to series, or vice versa. Plate 2,
e primaries connected in series and parallel
a porcelain block fastened to the terminal
in turn screwed to the upper clamp. The
to the case, and keeps the transformer firm-

of cast iron ¼" thick. Plate 2, Fig 6 and
the boxes for the smaller and for the larger
e boxes are tapped at the bottom, so that the
oved.
ner has been fastened in its place, the term-
t through suitable holes in the box, and in-
lain sleeves that fit into the holes.
are brought out at the back of the case on
secondary leads at the front of the box to
one to the other.
eeves are held firmly in place by means of
around them. This composition contains
s it to become quite hard when cold.
nnections for series and for parallel are al-
e of the box, and are as shown in Plate 2,
vely. The leads are crossed before they are
k to give this result. Fig. 4 shows how they
e secondary is made up of one coil on each
secondary is made up of two coils on each

e transformer, its size, and the primary and
re stamped on the cover. It only remains
he transformer is ready for use.
are tested at different stages during their
shall now proceed to describe how these

ts are made on all transformers where the
e wound for a voltage not higher than 3,000
than 1,800 volts.
legs or parts of transformers, after being

wound are placed together as shown in Plate 1, Fig. 11, and t for high potential tests, which are as follows:—

10,000 volts between primary and secondary, 10,000 volts tween primary and core, and 2,500 volts between secondary core.

In all high potential tests the voltage is gradually raised within 30% of the specified voltage, and there maintained fo period of three minutes. It is then gradually raised to the sp fied voltage, and there maintained for a period not exceeding seconds. When the transformer has a ground shield it is tried 10,000 volts between primary and shield, and 2,500 volts betw secondary and shield.

The high potential testing transformer is shown in Plat The movable coil is the primary, and is connected to the 1,040 line. The testing leads are connected to the terminals of "A," transformer being tested, and the voltage indicated by a Tho son's Electro-static voltmeter.

After the legs have been assembled together, and the tr formers baked in the ovens, they are tried for ratio test. transformer is allowed to pass, whose ratio is out more than of 1%.

A standard transformer having secondary taps of 52, 104, 115, 208 and 230 volts, has its primary leads connected to the 1 volt line, in parallel with those of the transformer to be tes A voltmeter is connected by means of a two way switch, to secondaries of the transformer, and to the corresponding sec daries of the standard, as shown in Plate 5, Fig. 1. The drop potential across the secondaries should be the same in both tra formers.

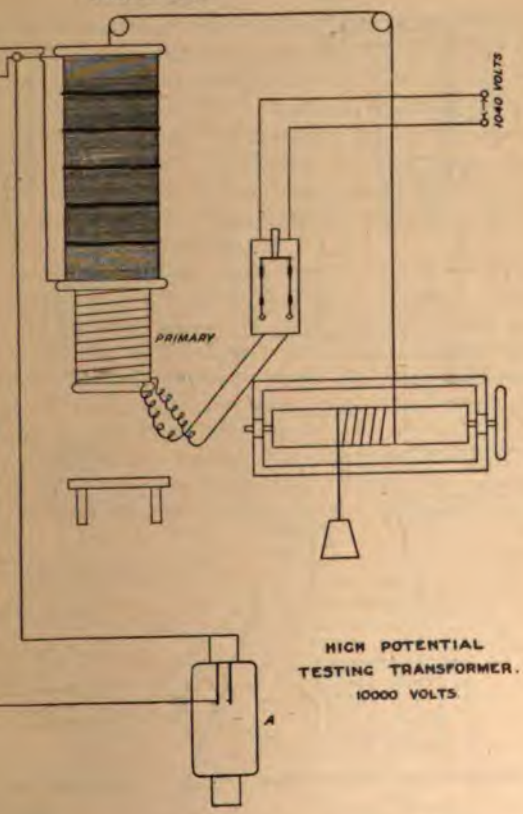
Secondly, immediately following the ratio test, the transfo ers are tried for "core loss," and the result carefully noted, the cold core loss, because the transformers are allowed to c before these tests are made. The tests are made at, as nearly possible, the voltage and frequency for which they were bu The following table gives the maximum allowable core loss fo few transformers.

Capacity in Kilo watts	Core loss in watts. 60 cycles	125 cycles
1.	42.0	42.0
1.5	50.0	50.0
2.5	65.0	58.5
3.0	71.0	55.0

This does not necessarily mean that the core loss of the ferent transformers is as high as stated in the above table, a matter of fact, it is very seldom that high: For example, in

ransformer which has an allowable core loss of 42 vas found to be only 26.5 watts. All transformers core loss are returned to the winding department. ss is measured from the low potential side of the avoid the introduction of high voltage in the test. current leads of a wattmeter, an ammeter, a

PLATE 4.



nce and the secondary coils of the transformer to series with the source of E.M.F., also connect a the potential leads of the wattmeter across the inal of the transformer, as shown in Plate 5, Fig. ential side being an open circuit.

speed of the generator has been regulated to give equency, and the voltage adjusted correctly, take

simultaneous readings on the three meters. The wattmeter i cates the core loss, and the ammeter the exciting currents.

Thirdly, the transformers are tried for the high potential t at the same voltage, specified for the legs before they are sembled.

After the transformers are assembled in the cases comp the following tests are made in the order given below. A tr

PLATE 5.

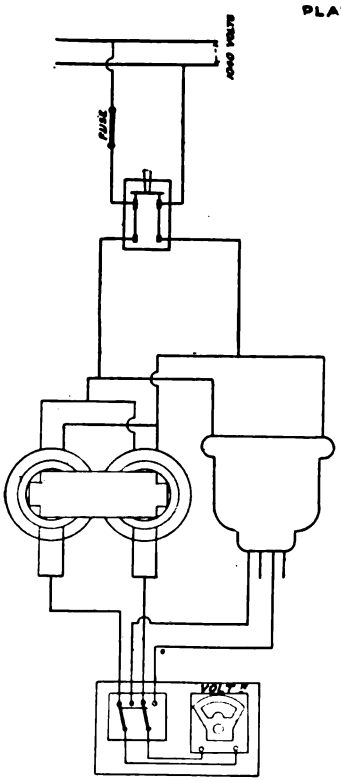


DIAGRAM OF CONNECTIONS FOR RATIO TEST.
FIG. 1.

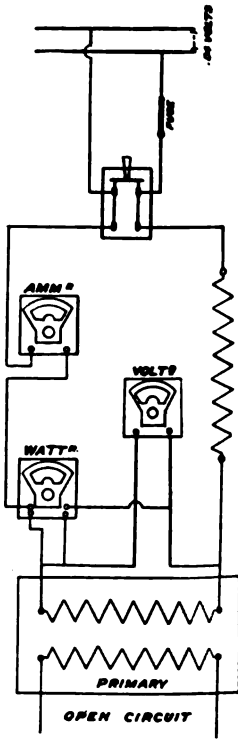


DIAGRAM OF CONNECTION FOR CORE LOSS.
FIG. 2

former having failed in any one test, and the defect having b remedied, has to be entirely retested, that is, all former tests discarded.

A.—High potential tests are given to the transformers ag and they must withstand the same tests as those previously s cified.

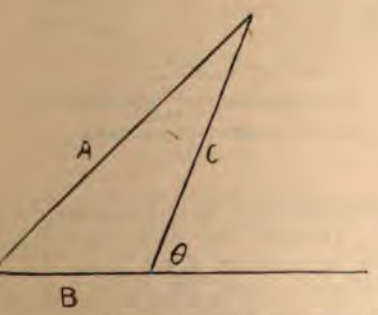
resistance of the secondary, and of each coil of
refully taken, the temperature of the room being
e time. This is done by passing a known D.C.
the coils, and measuring the drop of potential
inals of the coils. Plate 6, Fig. 1 shows the
ions.

regulation on a non-inductive load (bank of
ken. This is done in two different ways, depend-
f the transformers.

lier ones, where the full load can be conveniently
e across the secondary terminals is noted at full
load; care being taken that the line voltage has
n the readings. This result is obtained by tak-
both at "no load" of the drop across the second-
lar transformer, connected to the same line,
ith those taken on the transformer being tested,
r any variation, that might have taken place.
ows the connections.

ransformers the secondary is short circuited
ter as shown in Plate 7, Fig. 2, and the primary
so that the secondary will carry full load cur-
y voltage is noted, and the primary current also
emen's Electro-dynamometer, the product of these
iving the apparent watts used. A wattmeter
uit indicates the true watts.

s the primary voltage, for which the transformer
C the primary voltage used to give full capacity
ondary, then the regulation can be found in the



le shown in the figure, let B and C have the mean-
, and Cos θ represent the power factor, namely,
ed by apparent watts. Then A will represent the

necessary voltage of the primary to keep the secondary vol
normal at full load, and is equal to

$$\sqrt{B^2 + C^2 + 2\,B\,C\,\text{Cos}\,\theta}$$

A-B represents the increase in primary voltage necessar
prevent a drop in the secondary on full load, and the regula

$$= \frac{A\text{-}B}{B} \times 100\%$$

PLATE 6

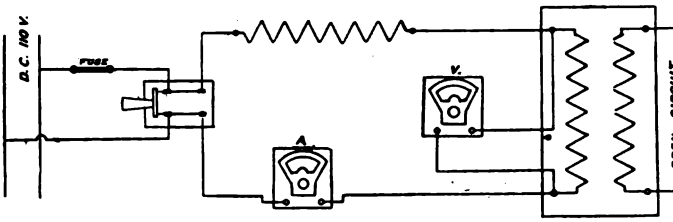


DIAGRAM OF CONNECTIONS FOR MEASURING RESISTANCE

FIG. 1.

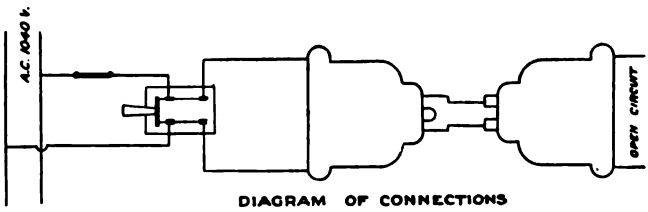


DIAGRAM OF CONNECTIONS FOR DOUBLE VOLTAGE.

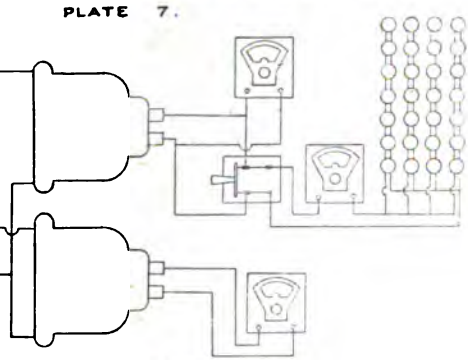
FIG. 2.

D.—All transformers are run at one-quarter overload for a
to dry them out. The next day they are run at full load, th
under 50 kilowatts for a period of six hours, and those over 50
W. for a period of eight hours, the object being to find the ma
mum rise of temperature above that of the air. They are
without oil, and the temperature of the core, the coils, and of
surrounding air is noted.

The rise of temperature as recorded by the thermomet
should not be over 40° C in any part of the transformer.

the transformers are banked for the heat
ere are two sets of transformers, each set
K. W. transformers. In each set they are
primary, and secondary to secondary. The
each set are connected in parallel to the
condaries of No. 3 in each set are connected
eing connected through a fuse wire.

PLATE 7.



IAGRAM OF CONNECTIONS
FOR
REGULATION.
FIG. 1.

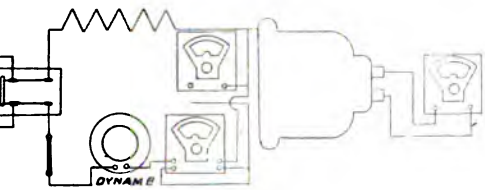


DIAGRAM OF CONNECTIONS
FOR
HORT-CIRCUIT REGULATION.
FIG. 2.

s are connected correctly, no current will
s will not be blown when a voltage is ap-
This is also a test for the "polarity." If
opposite polarity to the others, the connec-
one transformer through another, and the

nust have similar connections for polarity
testing department.

Two 7.5 K. W. transformers have their primaries conne in parallel to the 2,080 volt line. The secondaries are also nected in parallel, and placed in series with a bank of lamps, whole being inserted in place of the fuse, as shown in the fig

The full load current given by the two 7.5 K. W. transforn in parallel is equal to the full capacity current of a 15 K. transformer, and the load is regulated by the number of la placed in the circuit.

The 15 K. W. transformers supply the excitation current, the core losses, while the 7.5 K. W. transformers supply the current and the copper losses.

The economy of this method is quite obvious, as all the tr formers are tested, while the full current load of but one 15 K transformer is used.

In this case the two 7.5 K. W. transformers, or boosters been run at full load, and have thus been given the required run as well as the others.

Any transformer may be used as a booster, so long as its c city is great enough to give the required current, but if the rent it supplies as a booster be less than that required for load, it is not allowed to pass until it is given the required full run.

E.—Immediately after heat run, and while the transfor are still hot, the primary and secondary resistance must be a taken carefully, and the temperature of the air recorded.

F.—Each transformer is then excited to twice its normal tage, and run at no load for a period of ten minutes. This is by applying the required double voltage to the secondaries shown in Plate 6, Fig. 2, the primaries being on open circuit

G.—The core loss is taken once more to ascertain that not greater than in the previous tests. The hot core loss sl always be less than the cold core loss.

Finally the transformers are once more tried for the potential tests, at the same voltages as previously specified, the results of all the tests made out on suitable forms.

This completes the tests made on the transformers, and it remains to see that they are mechanically all right, that is, far as the terminal board leads, fitting of cores and cover are cerned, before they are handed over to the Stores Departmer

BUSINESS MEETING.

e opening of ballots for the election of mem-
hursday, November 17th, 1904, Mr. Phelps
Council, in the chair. Messrs. J. A. Jamieson,
J. W. Heckman, J. G. Legrand, and G. B.
appointed scrutineers, declared the following

MEMBERS.

F. C. MCMATH.
JR. W. J. STEWART.

ASSOCIATE MEMBERS.

F. A. PICKERING.
R. O. P. SCHREIBER.
LE. T. T. SIMPSON.
VRAY. D. R. THOMAS.
Y, JR. R. N. WILSON.
S. C. O. WOOD.

I CLASS OF ASSOCIATE MEMBER TO CLASS OF MEMBER.

ASER. A. E. HODGINS.
F. P. SHEARWOOD.

I CLASS OF STUDENT TO CLASS OF ASSOCIATE MEMBER.

AN. A. C. D. BLANCHARD.
H. L. BUCKE.

ASSOCIATE.

T. A. MORRISON.

STUDENTS.

A. T. WILSON.
E. L. BURGESS.
A. L. CUMMING.
E. F. S. DAWSON.
AN. J. V. DILLABOUGH.
K. W. DOWIE.
S. G. P. G. DUNLOP.

T. U. Fairlie.
D. C. Findlay.
J. R. Freeman.
A. C. Garner.
G. A. Gillies.
H. St. G. Hamersley.
J. Handley.
E. S. Hill.
V. J. Kent.
R. Lesage.
D. C. Livingstone.
F. H. Lytle.
T. C. McConkey.
J. J. MacNab.
J. G. MacPhail.
P. A. Masson.
S. A. Meade.
W. C. Meyerstein.
H. B. Miller.
H. H. Moore.
A. M. Morrison.
J. E. Newlands.
E. D. Normandeau.
F. H. Peters.
A. M. Phillips.
A. A. Putnam.
A. R. Roberts.
P. A. Shaver.
J. D. Shepley.
J. H. Sills.
D. Sinclair.
G. Singers.
R. H. Smith.
R. L. Squire.
Guy Tooker.
A. V. Trimble.
D. T. Townsend.
G. E. Vansittart.
Horace Walker.

MECHANICAL SECTION.

President—PHELPS JOHNSON.
Vice-President—M. J. BUTLER.

of the section was held on Thursday, November
Phelps Johnson in the chair. The following paper
e author:—

REMENT OF WATER BY A VENTURI METER,
IEWED FROM A NEW STANDPOINT.

By R. STECKEL, M. Can. Soc. C. E.

I. INTRODUCTION.

has perused with more than ordinary interest, and
ing reflection, the valuable paper on the measurement
small Venturi meter, contributed by Messrs. E. G.
ntab., D.Sc. Edin., and T. P. Strickland, M.Sc. Mc-
s read at one of the regular April meetings of the
. Lest some members of the Society might think,
ply a stereotyped way of showing his appreciation of
scientific experiments these gentlemen carried on at
ted hydraulic observatory which the authorities of
ity, with their characteristic generosity when the in-
ce are to be served, placed at their disposal, it may
lace for him to recall here the fact now probably
ght of by most members, that some twenty years ago,
made a number of experiments bearing on the sub-
cussion, and published the results in a pamphlet,
ewhat unique title of "An Essay on the Liquid Con-
The pamphlet was presented to the Royal Society of
nt to several other institutions of learning; it was,
ted in French and English in one of the Annual
Minister of Public Works of the Dominion Parlia-
ther on account of the matters treated being purely
immediate important practical application of any
th therein was then in sight), or whether on account
at primitive and imperfect apparatus the writer had
content himself with, he failed to inspire with

sufficient confidence the, no doubt, small number of persons perused the "Essay" with interest and close attention, to them to enquiring more deeply into the subject, or for reasons, no one has so far honoured him with a reas criticism for or against the theory advanced or the e rimental data determined. Now, however, that an important tical application of results of the phenomenon of the lateral munication of motion in liquids, has apparently turned up in nection with the Venturi water meter devised by Mr. Herschel writer is hopeful yet of having his views on the subject of li veins, if not formally confirmed or condemned by the scientific at large, at least intelligently discussed and criticized by the en eering profession.

The statement is made by Dr. Coker and Mr. Strickland: Mr. Clemens Herschel, M. Am. Soc. C. E., has shown in the pap read before the Society just named, Dec. 21st, 1887, that in Ve water meters applicable to mains of 1 foot and 9 feet diamete spectively, the flow is proportional to the square root of the d ence H between the heads which obtain in the two sections o *cone* forming the essential part of the meter, and that this rel holds good through the whole range of his experiments; the tity of water delivered being equal to $a\sqrt{2gH}$, where g denote acceleration of gravity and a is constant denoting the product o area of the smallest cross section of the meter by a factor n equal to unity. The word *cone*, the writer takes for granted, is by the gentlemen who conducted the experiments at McGill Un sity, above referred to, for brevity's sake, to designate the convergent-divergent ajutage, or momentum transformer, constitutes the Venturi meter.

As the writer views the matter, the flow is shown by Mr. chel, to be nearly proportional to the square root of the head responding to the difference between the pressures at the two tions of the ajutage which are looked upon (wrongly believes) as constituting the essential part of the meter, for effective hydraulic heads falling within the limits of 11 fee ¼ foot, and which correspond therefore to but 33 diameters and a diameter of the throat of a meter applicable to a 1 foot main within the limits of, say, 2 feet and .05 foot, or ⅜ and 1-60 of a meter of the throat of a meter suitable for a 9 foot main. It c well be said that these limits, although embracing nearly al experiments undertaken by the inventor of the Venturi meter, as the writer knows, afford a very extended series of data as relations between head and diameter of pipe are concerned. over, the maximum up-stream pressure or head of wate

ch efflux took place in Mr. Herschel's Holyoke exper-
rely ½ of the ordinary total pressure of the atmos-
ft.), by which the discharge of water from pipes and
most invariably affected to a greater or less extent.

xperimenters point out in the "Introduction" to their
determination of the pressure at the down-stream
er is not essential for practical water measurements,
id pressure was measured and used by them merely
of determining the total loss of head in the instru-
other part of the paper they assume, in common with
ted writers on hydraulics, that the difference between
$_1$ and P_2 which obtain respectively at the extreme up-
n-stream ends of a meter, represents the loss of head
ion during the passage of the water through this
s hypothesis the writer has always felt inclined to
it appears to him to be unfounded.

ve place two reservoirs R_1 and R_2 side by side, and
y a horizontal pipe or tube having a length of less
diameters, which relation holds good approximately
meter. Now, let us stop up the connecting pipe
fill R_1 and R_2 with water, until the pressure at the
in the reservoir R_1 becomes equal to P_1, and the
end in reservoir R_2 becomes equal to P_2, where $P_1 >$
t us remove the stopper from the connecting pipe so
water to flow from R_1 into R_2. The writer does not
can assign, in such case, a first cause for the flow of
R_1 to R_2 other than the difference in the pressures
imself can discover none. It is immaterial what par-
e connecting pipe may have, the first cause of the flow
R_1 to R_2 must be the pressure corresponding to
if the water levels in the reservoirs R_1 and R_2 are
intained at their original heights or the pressures at
tensities, the cause of the flow will remain invariable,
always the constant excess of the pressure P_1 over
shown more plainly a little further on the sections of
oining the Venturi at both ends constitute reservoirs
r to R_1 and R_2 and serve the same purposes; the up-
tion doing duty as a source of supply, and the down-
tion as a receiver of the liquid which has to pass
f them, as well as through the connecting meter pipe.
and only first cause of the flow of liquid from R_1 into
$_2$, cannot at the same time be a rational measure of
d due to friction generated by the passage of the
the connecting pipe. Besides, the friction head

generated by water running in a straight pipe having a leng less than 15 mean diameters and which comprises a convergent and a gradually enlarged outlet, can only form a comparatively s percentage of the velocity head, perhaps even 25 per cent.; but inconceivable that it could ever reach 70 per cent. or more of head, as was the case, for instance, in groups of experiments N 5, 6 and 21 of Table G at page 323 of this paper.

The methods of determining the heads and measuring the charges followed by Dr. Coker and Mr. Strickland could not e be improved on, and the results obtained as tabulated by gentlemen and illustrated by diagrams, the writer has no doubt, inspire every engineer with confidence in their accuracy and ability in every particular, more especially as there was appar no leakage of any kind in the measuring tank. It might be obse however, *en passant*, that while the dimensions of this tank given as being 9 feet by 6 feet by 3 feet 6 inches of which, pre ably, the first represents the height, yet it is stated that one g corresponds to 0.087 inch in height. The writer finds that w tank measuring 6 feet by 3½ ft. this last height would be 0 inch; but possibly the figures 6 feet by 3½ ft. are not absol correct, or else the conditions under which the measurements made, were such that a greater degree of accuracy than, say, w one half a hundredth of an inch, could not be secured.

That the colour band introduced by the McGill experimente a glass meter of reduced size should remain straight in the u or convergent inlet pipe, and assume a wavy condition in the di ent receiver, the writer conceives to be due to the fact that in inlet the vis viva of the vein formed therein is continually incre in the direction of the flow, while in the divergent receiver moving mass is being continually increased at the expense o living force, going in the same direction, and a cone with str sides is not altogether an ideal receiver in which the transforma of momentum can be effected gradually, viz., without some pu tions and eddies being induced and corresponding losses of en experienced. Probably a better kind of transformer or conve of living force into pressure would be a conoid similar to that by "Giffard" for his injector of feed water into steam boilers.

The word throat is used herein only to designate the contra junction between the two conical frusta of the meter; it seem the writer that the reference by the McGill experimenters, to l the wide entrance to the convergent conical inlet pipe or mo piece and the flared outlet of the divergent receiver, as throat common with the said contracted junction, although perh strictly speaking, correct from their point of view, is not, un

desirable extended application of that short

umption that Daniel Bernoulli's theorem holds
the water passed through the Venturi, it is
if this hypothesis is, in general, a safe basis
on, unless we are prepared to make a distinc-
ion of a difference of head between two points
of conduits and reservoirs which corresponds
the portion due to advantage of position as
the force of gravity.

ed by the three sets of Messrs. Coker and
ents which are numbered (18, 19, 20)—(21, 22,
proved more particularly interesting to the
that the velocity and the Pressure P_1 at the
here apparently sufficient to produce a nearly
one corresponding to the Pressure P_0 exerted
ceeding 33 feet in height, around the throat or
ontraction. Notwithstanding that the pressures
m 13.165 to 20.958 feet, and the velocities in a
, the indications P_0 of the vacuum gauge were
same; for the very good reason, it may be
was no atmospheric pressure left above that
.0 foot water column which the centre gauge

he barometric pressure is practically reached
rse, not be gainsayed ; but does it follow that
e ceases to be available as an indicator of the
h liquid is drawn through the throat of the
ning fluid motion in general abruptly fail, or
and a new state of things springs into exist-
seem reasonable. Might not, for instance, a
nstructed that would run full from end to end
essure P_1=50 feet, the same as under a press-
ly a comparatively small back pressure P_2 to
vergent-divergent ajutage of suitable propor-
such case, as appears to be possible, what
nce between the condition of a liquid flowing
a meter in a perfect vacuum created under an
of 20 feet and one created under a pressure
more; the up-stream pressure working in each
ream pressure P_2 equal to, say, $\frac{1}{4}$ P_1 or less ?
bers rightly, it was the physicist Hachette who
ge from a reservoir through a short cylindrical
ube is just the same, just as copious, when

efflux takes place in a vacuum, or under the receiver of an air p
as when the liquid flows in the open air, so that, as this experime
affirms, the atmosphere is not primarily responsible for the incre
volume of liquid discharged through such tubes in a unit of tim
comparison to the quantity afforded by a simple orifice in a
plate of the same diameter, during the same time and under
same pressure. It is singular that the value 0.9537 determined
co-efficient C should be larger for $P_1 = 20.95$ ft., than that comp
for $P_1 = 16.123$ ft., viz.: 0.9494, while the vacuum induced in
throat remained constantly at the maximum of --33 feet v
column pressure. The increase in C from 0.9494 for $P_1 = 16.12$
to 0.9537 for $P_1 = 20.958$ feet, slight as it is, seems to be an indi
or rather a veiled indication that the method of determining the
theoretical co-efficient of velocity is faulty, possibly based
wrong principle, or that co-efficient C applies to a velocity re
ing from a combination of two motions of translation due to di
causes varying in contrary directions.

II. The Conditions of Flow in Convergent-divergent Ajut

According to the views of the writer, when a stream of wat
flowing through a Venturi Meter the drop observed in the pre
from P_1 at its upper end to P_0 in its throat,—is an inevitable
sequence—but not the first cause of the motion induced in
throat, in the same way as the difference $(P_1 - P_0)$ betwee
pressures P_1 and P_0 on the up and down-stream sides respect
of an orifice in a thin wall of a reservoir, is properly held to b
first and only cause of the flow of water through the said o
The increased velocity which obtains in the throat of the mete
in the writer's opinion, primarily the result of the transform
or transmutation of the mass and velocity factors of the pr
constituting the momentum of a volume of discharge in a
time, not exceeding the total quantity of water that can be deli
in the same time by the cylindrical pipe when unintercepted
meter.

The writer submits, we are not warranted to assume tha
theoretical velocity v_{CED} in the section of maximum contra
$\overline{CED}$ of a composite or convergent-divergent ajutage such as the
turi meter, must, in general, be a continuous function of $(P_1$
such as that above quoted, viz.: $a\sqrt{2g\,(P_1 - P_0)}$, notwithsta
the fact that by using this formula, results have been arrived at
responding. apparently, within narrow limits, to the velo
which actually have obtained in some meters experimented

ssures. The vertical flight of a body falling ough a height corresponding to $(P_1 - P_0)$, the id function, and the draft or forced discharge of comparatively short throat of a Venturi meter, onably artificial, are motions generated under ditions.

riter is able to judge, the flow of liquid veins ie propagation of liquid motion in general, must remely rapid oscillations or gyratory movements all pervading ether, similar to those of the real our senses are rendered conscious by the pheno- and electricity. And if streams of water projected ugh orifices in thin plates in directions perpendi- of the former, assume the form of the conoid under the name of "the contracted vein," instead it is due to the interference with the otherwise liquid particles by such very rapid molecular tal movements of varying amplitudes, periods, ecise nature of these transcendental gyratory or would be rash, if possible, for anyone to ven- he tangible and visible changes they produce in ms the writer endeavoured to point out in his erein referred to. It would seem that the first application of the theory advanced in that paper, onnection with the prospective construction and of water meters suitable for measuring quan- ied under high pressures through small pipes for would prove as satisfactory as the present Ven- the measurement of the larger volumes required ks and industrial or manufacturing purposes, s are delivered generally with smaller and more

ine what would happen, should we begin by in- r cone, or convergent velocity generator, or W* of the Venturi meter (See Plate 14), by main or supply pipe, and afterwards complete the divergent receiver and pressure accumulator the convergent velocity generator or delivering the main, without in any way interfering with , we convert the portion of the pipe on the up-

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tters which refer to lines or areas have, as a rule, been overlined ebraical quantities.

stream side of the said convergent tube into a reservoir (R which the water is continually kept in a state of overflow. For, such portion of the quantity of water originally carried by the duit when free of interceptions throughout its whole length, can be discharged, as will find its way through the small end $\overline{CED}$ o inlet tube with a velocity slightly in excess of that which obt in the free pipe; the balance having to go to waste or to swel quantity stored at the source of supply. And it will furth noticed, that the increase in the velocity of the liquid in the base $\overline{CED}$ of the velocity generator is the result of the conve of a portion of the living force of the originally free flowing st into hydraulic pressure or head. The stream at its passage thr the tip end $\overline{CED}$ of the convergent conical inlet of a "Ventur the ordinary construction, may be considered to come out approximately under the same conditions as would a freely tracted vein $\overline{ABDCA}$, which is projected under the same pres through an orifice $\overline{AOB}$ in a thin plate, inserted in the flat wal of a reservoir standing on the up-stream side of the said e base, viz., at a distance $\overline{EO}$ equal to about one diameter $\overline{CD}$ o base; the orifice having a diameter equal to about 1¼ times of the same base $\overline{CED}$ or throat of the meter. But since the of this throat is only from 1-9 to 1-18 of that of the main i meters thus far constructed, as closely as the writer can make the quantity of water now discharged in a given time is not sli greater than from 1-9 to 1-18 of the quantity carried in the time by the pipe previous to the introduction of the velocity rator; abstraction being made of temporarily decreased resist through the same system of conduits.

Let us now complete the Venturi meter by adding withi main, to the upper conical frustum or convergent velocity gene $\overline{WCDZW}$, at its small base $\overline{CED}$, the divergent receiver and pre accumulator $\overline{CFGDC}$. The original stream of uniform cross se and velocity flowing through the free pipe, which was at first clally contracted in order that a vein might be formed within i would flow approximately under the same conditions as the na *vena contracta*, is now, on the contrary, artificially expanded in divergent receiver within the limits of the lateral communicati liquid motion, fluid pressure is stemmed in the receiving rese R_2 or down-stream section of the water main, and an increase charge is produced through the complete meter, simultane with an ultimate lowering of the pressure from P_1 to P_0 an which discharge now approximates more closely the quanti water that can pass in the unintercepted pipe. Notwithstan

omentum transformation and the accompanying
n, the motion of the liquid in the completed con-
ajutage continues to be governed throughout, by
nental laws of the molecular (or atomic or cor-
nics of fluids, in accordance with which the
contracted vein just defined is formed.

s pamphlet on the "Liquid contracted veif" it is
ie freely contracted liquid vein $\overline{UACDBVU}$ (See
d from the action of gravity after leaving the re-
elocity of translation, vel_{CED}, at any cross section
s projected through small orifices $\overline{AOB}$ having a
½ inch and under small pressures of a few inches,
ie comparatively simple relation:

$$_{CED} = 0.66 \sqrt{2gh} \left[\frac{\sqrt{.44s + x}}{\sqrt{.44s + .44x}} \right] \qquad \text{(A)}$$

e co-efficient of theoretical velocity of efflux $\left(\begin{smallmatrix} \text{coeff.} \\ \text{veloc.} \\ \text{eff.} \end{smallmatrix} \right)$
$\overline{OB}$,

ation of gravity per second,

eight of the water column pressing on the orifice,
t representing the ratio of the total head h to the
the plane of the orifice, and also the fraction of
growth of the vein, corresponding to a period of
cursions of liquid molecules (or atoms or still
les) in their ethereal orbital motions or oscilla-
the liquid projected from the reservoir R_1—which
period of up-stream excursions of the molecules
oscillation or gyratory movements, or—which
ng—the ratio of the growth or progress of the
increment of time taken up by an up-stream excur-
s in an ethereal oscillation proper to the liquid pro-
reservoir, to the growth or progress of the vein dur-
nt of time taken up by the down-stream excursion
the same orbital motion or oscillation. This co-
s in value slowly as the hydrostatic pressure on the
and possibly also slightly as the area of this orifice
remains sensibly constant for the same vein, more
ards the down-stream side of the orifice.

r denotes the radius $\overline{OA}$ of the orifice $\overline{AOB}$ and

s, a space equal to the penetration $\overline{OP}$ of the complete vei
the reservoir R_1, or the distance $\overline{OP}$ from the plane of the
$\overline{AOB}$ to the plane $\overline{UPV}$ in this reservoir, where all bodily fo
motion of liquid theoretically ceases, divided by .44, viz.: a
equal to $\frac{OP}{.44}$ This auxiliary space varies roughly, a
experimental determinations, between $\frac{1}{2}$ r and $\frac{3}{4}$ r according to
sure.

x and y represent respectively rectangular co-ordinates $\overline{O}$
referred to the centre O of the orifice as origin; a diameter
the orifice prolonged at both ends being taken for the axis of
the perpendicular $\overline{POEX}$ to the plane of the orifice $\overline{AB}$ p
through the center O, for the axis of X.

The constant numerical factors 0.66 and 0.44 are here used
sionally in place of variable co-efficients of efflux $\left(\frac{\text{coeff.}}{\text{veloc. orif.}}\right)$ and
of acceleration i_v; in order to better fix the ideas of the rea
the subject. It must be remembered, however, that these num
factors vary materially; both increasing a little simultaneously
the diameter of the orifice and diminishing as the pressure incr
For a vein projected into air through a small orifice under a
great head, the factor 0.44 may become 0.30, while the facto
may drop to 0.55 under similar conditions, judging from a li
number of determinations of corresponding co-efficients of co
tion and co-efficients of velocity of efflux of circular freely
tracted veins.

As already intimated, the contraction of the liquid vein
jected freely from a reservoir through an orifice in a thin
the writer conceives to be caused by the combination or interfe
of very rapid ethereal orbital movements or oscillations of
cules—possibly of augmented amplitudes in comparison to
of similar movements obtaining in the body of the reservoir,
are proper to the liquid at rest—with the uniform bodily m
that would otherwise be imparted to the liquid matter in a
tion perpendicular to the face of the orifice plate, if the vei
abstracted from gravity, by the constant hydrostatic pressu
the permanently balanced molecular forces acting in rear o
orifice. In establishing the direction of the flow this pressur
writer surmises, deflects the revolving or oscillating liquid pa
from their hydrostatic positions so as to render the planes of

parallel (or nearly so) to the axis of the fluid
ng infinitesimal periods of up-stream and down-
liquid particles in the vein motion; the hydro-
ently also determines or regulates the absolute
ticles that can flow through the orifice in the
e number of times the liquid slice in the orifice
id time unit.

l uniform motion of translation of liquid
is thus constantly being alternately acce-
during infinitesimal increments of time by the
al, oscillatory or gyratory forces taken succes-
rection as the flow and in the opposite direction,
ner a moving body would be drawn along at
r slowed up by swinging pendulums, according
eir spheres of influence or meet or collide with
or the other of the verticals passing through
nsion; the ultimate result being that the rate of
every circular freely contracted liquid vein in-
tant of its formation, viz.: its motion, or rather
tinually accelerated from its origin in the plane
outward, or on the down-stream side of this
on its up-stream side or going inward. So that
tional velocity of formation of the vein in the
is denoted by the square root of the propor-
of the vein motion during an up-stream excur-
viz., by $\sqrt{0.44} = 0.66$, as above stated, its final
y of formation or translation must necessarily
square root of the proportional acceleration of
ing a down-stream excursion of molecules, viz.,
an infinite distance from that plane on its
nd the proportional velocity of formation must
a certain finite distance measured inward from
along the longitudinal axis of the vein. For, as
that can pass through an orifice in a thin plate
necessarily invariable when the outward motion
constant head or pressure—in order that the
longitudinal translation of the liquid molecules
ontinually outside the reservoir during alternate
in the ratio of 0.44 for the up-stream excursion
the down-stream excursion increment and
e reservoir in the ratio of 1 to 0.44, without
ne vein of which the said molecules form part
r longitudinally in the first case or laterally
, an indispensable condition is that: (*a*) the

area of the cross section of this vein must continue to dimini
the down-stream side of the orifice in the inverse ratio of th
crease of the velocity of translation, until the initial propor
velocity of vein formation of $\sqrt{0.44}$ becomes ultimately equal t
—(*b*)the cross section of the vein must continue to increa
the up-stream side of the orifice in the inverse ratio of the dec
of the velocity of translation until the initial proportional ve
of vein formation denoted by $\sqrt{0.44}$ becomes reduced to $\sqrt{}$
matter what may be the particular law according to which the
has to grow or develop itself, as determined by its size an
absolute celerity of its formation in space; that is to say, wha
may be the precise nature of the continuous function which
nects at any point of the trajectory, the diameter of the vein
its longitudinal development, and the diameter of the orifi
which it originates.

If we denote by f the intensity of the ethereal force by whic
sum total or the whole mass of the molecules in a cross secti
a liquid slice, of a small circular vein formed under a mo
head is drawn forward and displaced bodily, during a peri
stream ethereal molecular excursions, then will $0.44f$ represe
intensity of the ethereal force urging on the same liquid slice
direction of the flow, during the corresponding period of up-s
excursions of molecules, and $\frac{44f}{f} = 0.44$ will correctly rep
the ratio of the rate of bodily acceleration of the vein durin
period of an ethereal up-stream excursion of molecules, to th
of acceleration in the corresponding period of down-stream
sions of molecules. In order, therefore, that the outward or fo
motion imparted by a constant hydrostatic pressure in the res
to the liquid matter might remain uniform over any portio
of its trajectory, and the vein might assume a uniform cross s
from O to E, the molecular oscillations or orbital movements
have to cease altogether, if this was possible, with matter c
tuted as we conceive it to be.

Again, as already stated, the origin of the formation of a
contracted vein, such as $\overline{ABDCA}$ (Plate 14), is evidently in the
of the orifice $\overline{AOB}$ through which it is projected by the hydr
pressure—and the complete fundamental freely generated
comprises two conoidal frusta which are formed simultan
on both sides of the said plane. On the outside of the reserv
the vein grows in the direction $\overline{OX}$ of the flow and on the
in the opposite direction $\overline{OP}$.

evelopment or growth of the vein $\overline{AUPVBDIJCA}$ on
nd $\overline{OP}$ of the plane of the orifice $\overline{AOB}$, the following
ow must obtain, viz.:

the reservoir R_1, the resultant ethereal forces of the
cular excursions in each liquid slice, such as $\overline{LQN}$.
direction $\overline{OP}$ as the vein-formation which takes place
O towards its upper end P, and on the exterior por-
vein trajectory the direction of the said resultants in
e, such as $\overline{CED}$, is opposed to that of the vein propa-
owards its lower end X.

contrary, inside the reservoir R_1 the direction of the
al forces of the extremely swift down-stream mole-
s in each liquid slice, such as $\overline{LQN}$, is opposed to the
the vein-formation from O towards P, and the direc-
l down-stream resultants in each liquid slice, such as
side of the reservoir, is the same as the direction in
grows or is developed from O towards X.

ars that when the conditions of flow of the liquid are
rfect: at any stage of the inward propagation or
ein from $\overline{AOB}$ towards P, such as when the plane or
$\overline{QN}$ is being passed, the supply of liquid within reach
outward by the hydrostatic pressure, is always in
uantity needed to form the vein at and below, or in
section. Hence, as already intimated, inside the reser-
circular liquid vein must of necessity continually ex-
out laterally and become shortened for a very great
infinite length of time, viz., until the negative vein
ce—f to which the outflowing liquid is subjected dur-
m molecular excursions, has completely obliterated or
mentum imparted to the mass of the liquid slice in
by the force $0.44f$, and a plane of perfect rest $\overline{UPV}$,
ily translation of liquid in the direction $\overline{POX}$, is
the Reservoir R_1, at a distance $OP = 0.44s$ from the
d orifice.

s no reason why the rate at which the motion im-
to the mass of the liquid slice in the circular orifice
ginning of the vein formation is being extinguished
uld be greater or less at one time than another dur-
growth of this vein when it is abstracted from all

disturbing ambient liquid under pressure between the planes and $\overline{UV}$. The extent of the penetration $\overline{OP} = 0.44s$ of the vein the reservoir R_1 may, therefore, rationally be considered to r sent the space in which the uniformly retarding fo f applied to the mass of the elementary circular liquid AOB moving outward with the velocity of the positive formation, due to the accelerating force $.44f$—which obtains i orifice $\overline{AOB}$, brings the said slice to rest as regards bodily tra tion towards O and X by reason of the gradual expansion o vein section; s representing the space which the mass of the mentary circular liquid slice AOB spread over a transverse se $\overline{UPV}$ of comparatively infinite extent, must describe this plane $\overline{UPV}$ of absolute rest as regards bodily tra tion of liquid particles—while being solicited by the unifo accelerating ethereal force $.44f$—in order that the velocit positive vein-propagation in the direction $\overline{OX}$ which is prop and does actually obtain in the plane of the orifice $\overline{AOB}$ ma generated.

Hence, considering that in all uniformly accelerated and all formly retarded motions, the velocity generated or the velocity come, as the case may be, varies in general as the $\sqrt{\ }$ of the space cribed from, or as the $\sqrt{\ }$ of the space to be described up to a of rest, the foregoing train of reasoning leads to the conclu that at any point of the vein trajectory, such as Q within without the reservoir R_1, the total proportional velocity of formation generated from a state of rest in either the inside $\overline{LGN}$ or the outside slice $\overline{CED}$, in virtue of the subjection of the of the liquid slice AOB to the force $0.44f$ may truly be represent $\sqrt{.44\ (s + x)}$ and the corresponding total proportional veloci vein propagation generated in either the slice $\overline{LQN}$ within, o slice CED outside the reservoir, in virtue of the subjection o mass of the liquid slice $\overline{AOB}$ to the force f can also be pro denoted by $\sqrt{44\ s + x}$.

Now, as already stated, it is clear that in a circular, theoreti perfect, freely contracted liquid vein, the *actual* velocity of its mation must, in general, vary directly as the ratio of the total portional velocity represented by $\sqrt{.44\ s + x}$ which is due t subjection of the mass of the elementary slice of liquid in orifice $\overline{AOB}$ to the ethereal force f from a state of rest, to the proportional velocity represented by $\sqrt{.44\ (s + x)}$ which is d the subjection of the same mass to the ethereal force $.44\ f$,

est, viz., the growth of the vein must vary as the

$\frac{x}{+x)}$ as otherwise the liquid stream could not re-

that is to say : on account of its longitudinal or ng up, or both, no vein would be formed.

lly, in all such fundamental freely generated cir- following relations must hold good, viz., we must

$$\left.\begin{matrix}\text{loc.}\\ \text{ect.}\\ \overline{\text{ED}}\end{matrix}\right) :: \left\{\frac{\sqrt{.44s+(x=0)}}{\sqrt{.44[s+(x=0)]}}=1\right\} : \frac{\sqrt{.44s+(x=\overline{\text{OE}})}}{\sqrt{.44[s+(x=\overline{\text{OE}})]}}$$

ng the 3rd and 4th terms of this proportion by

we obtain:

$$) : \left(\frac{\text{Veloc.}}{\text{sect.}}\right) :: \sqrt{.44s+.44x} : \sqrt{.44s+x}$$

e:

$$\frac{\text{OB}}{\text{ED}} = \frac{\overline{\text{CE}}^2}{\overline{\text{AO}}^2} = \frac{y^2}{r^2} = \frac{\sqrt{.44s+.44x}}{\sqrt{.44s+x}} \quad (\text{A}_1)$$

esents the space $\overline{\text{OP}}$ in the prolongation of the $\overline{\text{XEO}}$ of the vein, depending on the size of the tensity of the hydrostatic pressure, at the inner space all bodily translation of liquid, must come nto the reservoir and has to originate coming out section $\overline{\text{UPV}}$ of the vein being, under theoretically of flow, as already explained, one of compara- tent and complete immobility as regards longi- n of liquid particles.

reservoir, the pressure in and around the freely mains clearly invariable, inside however, or on the the orifice, where the out-going stream of mole- sly expanded and its advance correspondingly re- re in the vein increases gradually above that of sphere (some 30 inches of mercury) going inwards, ecomes equal to the sum of the said barometric hydrostatic pressure in the reservoir. This max- ust evidently obtain at the section $\overline{\text{UV}}$ of compara- n-area and perfect immobility, and it is only after ement of elementary liquid slices has reached the

said asymptotic plane $\overline{UV}$ that the flow becomes permanent and t
vein can be considered to be complete within the reservoir.

By taking the reciprocal of equation (A_1), multiplying it by $vel._{A}$
and replacing $vel._{AOB}$ by its value: $0.66\sqrt{2gh}$, we arrive at:

$$Vel._{CED} = 0.66\sqrt{2gh}\left[\frac{\sqrt{.44s+x}}{\sqrt{.44s+.44x}}\right]$$

that is to say, at equation (A) quoted above, page 253.

The writer must here confess that the description of the pr
cess of the formation or growth of a freely contracted circul
liquid vein, from its origin at the orifice in the wall of a reservo
under the government of an ethereal force acting with nearly co
stant alternating intensities, and a hydrostatic pressure having t
particular duty to perform of establishing infinitesimal periods
alternate unbalanced up-stream and down-stream excursions
liquid particles, besides that of regulating the celerity of the fl
in a direction perpendicular to the plane of the orifice, which
has just endeavoured to give as concisely and logically as he cou
sounds at times, even to himself, when reading over cursorily c
tain parts of this physico-mathematical literary effort, much l
an attempt at a stretch of the imagination, for the purpose
giving mankind an insight into the system of locomotion in vog
on one of our sister planets of the solar system, or with so
equally visionary object in view.

There exists furthermore, no doubt in the writer's mind th
most members of the Society are cognizant of the fact prominent
brought out in the works of Citizen Z. B. Venturi and referred to
other authorities on hydraulics and hydrodynamics: that the math
matical determination of the generating curve of the well-know
conoid affected by the freely contracted liquid vein projected fro
a reservoir under a constant pressure through a circular orifice in
thin plate, is a problem which has baffled some of the greate
geometers of the past two centuries or more. For this reason, if f
no other—the writer has some misgivings that notwithstanding t
demonstration herein above given by him, many readers of th
paper will still be disinclined to be firmly convinced, that a tr
solution of this very complex physico-mathematical question of su
long standing has actually been found by him about a quarter
century ago—and will consequently be little disposed to devote so
of their valuable time to the concentration of their powers of pen
tration on the subject under discussion, with a view of satisfyi
themselves of the soundness of the theory herein imperfectly ou

king a hand in its further development and practical

r feels, therefore, that he may be pardoned if, under the s, he considers it is advisable to re-assure the members y on the above points before proceeding any further in rain, by placing before them for inspection Plate 15, reduction of a lithographic facsimile of an enlarged record taken about 1869, of a real circular acted vein of water, projected under a constant t 14 inches through an orifice 0.53 inch in diameter, e centre of a brass plate 1-10 inch thick and about 4 meter, with its inner face countersunk concentrically ice to very nearly the shape of the frustum of vein he up-stream side of orifice $\overline{AOB}$ of Plate 14. This lready appeared, full size, in the writer's "Essay on the quid vein"; but this time he added the corresponding rve of the hyperbolic conoid assumed by the vein which by equation (A); indicating it by a dotted line plotted ordinates measured from an axis of abscissas purposely one-tenth of an inch away from the longitudinal axis o as to prevent the outline of the natural vein as photo- n being partly obliterated by the theoretical curve with cides almost perfectly.

r value of the co-efficient $i_{,,}$, viz.: $0.80^4 = 0.4096$, being or 0.44, r taken at 4.4578 inches and s equal to 0.5419 r, ntal equation (A) became in this particular case:

$$y = \frac{4.4578\sqrt[4]{0.4096(0.5419 \times 4.4578) + .4096x}}{\sqrt[4]{.4096(0.5419 \times 4.4578) + x}} \qquad (A_2)$$

d curve constructed with the ordinates computed with uation (A), evidently follows very closely, in fact almost oughout, with the outline of the enlarged photographic a cross section which is about 8 inches from the orifice te 15), where the vein of water commenced to expand a of continuing to contract the same as the theoretical expansion in the natural vein may have been caused by e opposed to the flow of the liquid by the atmosphere, eviation of the orifice from a perfect circle.

it will be noticed, the writer had to assume that the theoretical orifice was 0.33 inch back of the outer rass plate in the enlarged vein, or nearly two hun- inch in the natural vein, whence it may be concluded

that the precise position of the plane of this orifice is involved some uncertainty. This is no doubt the case to a limited exte but inasmuch as the very short piece $\overline{Aa}$ of the freely contrac liquid vein within the reservoir and which could therefore not photographed, had so very nearly the same shape as the cavity the brass plate that it could be considered to be co-incident with the outline of the visible part of the vein could not have b appreciably affected by this shifting back of the plane of the th retical orifice into the reservoir. This course was moreover fu justified, in view of the well-known fact that, according to act measurements of veins made by various hydraulicians, the efficient of contraction of such a vein as that under consideratio about 0.80, or perhaps between 0.79 and 0.80 ; but on account of free flow through a simple orifice pierced in a thin flat side o reservoir being interfered with by water extraneous to the conoi frustum which is assumed by the theoretically perfect vein wit the reservoir, to a greater degree than in the conoidal cavity form in the brass plate, the vein contraction taking place in the form case must also necessarily be slightly greater than in the latter.

The writer has also preserved the original photographic rec from which the lithograph was made. This enlarged photogra has now become nearly white from old age, being one of seve enlarged photographic records of liquid veins made about thir five years ago at the request of the late regretted T. Trudeau, E who was at the time Deputy Minister of Public Works,—by writer's old friend, Mr. S. McLaughlin, the former very able a painstaking photographer of the said Department, who is now resident of Riverdale, California. In making these enlargeme Mr. McLaughlin used a revolving solar camera specially devi and operated by him with a view of securing a clear and sharp o line of the veins. A singular feature of the enlarged vein un consideration is, that its longitudinal axis is a full degree and half off the perpendicular to the face of the brass plate and he to the plane of the circular orifice, pointing upwards in the dow stream direction; this is, presumably an effect of the perspect of the field taken in by the camera when the diminutive negat of the liquid vein used for its enlargement was made.

In equation (A) the factor $0.66\sqrt{2gh}$ of the second member, presents the velocity with which the liquid is ejected from the res voir at the orifice in a thin plate under the pressure exerted by water column of the height h, on the supposition that the liquid composed of infinitely small balls, the same as extremely fine sh rolling very swiftly over each other, or, rather, having extreme rapid gyratory or oscillatory motions.

ing factor, viz.: the fraction :

$$\frac{\sqrt{.44s + .44x}}{\sqrt{.44s + x}}$$

braically the law according to which the impelled particles are permitted to make their way through h ether, under the influence of their extremely rapid yratory movements.

ordance with the principle of the conservation of the momentum generated by the hydrostatic pressure ntracted vein under the government of the molecular es f and $.44f$ can go to loss or be destroyed, we can transform that vein-momentum by increasing the t the expense of the velocity, or vice versa. All such s, where an increase of the mass is compensated for in the velocity, are invariably accompanied by an sure going in the direction of the flow, and they ause a small loss in the vis viva of the liquid stream; ing force being used up in overcoming friction, vis- converted into heat.

of the incompressibility of liquids, it is not practi- se directly the velocity of translation at any point of uid vein at the expense of the moving mass, by con- in section to a greater extent than this is being done ontracted liquid vein. We can, however, notably in- ing mass at the expense of the velocity by taking he phenomenon of lateral communication of motion. kind of transformation that is effected when we a conoidal tube having the form of a freely con- vein such as JCAUPVBDIJ, some such convergent- ge as LACFGDBNL or WCFGDZW, the throat of same diameter as a cross section CED of the con- ken not too far away from the orifice AB, and which . On the down-stream side of the section of maxi- n or throat CED, a tube or receiver of greater capa- orresponding frustum of freely contracted vein such is to say: either a tube with sides diverging in the f the flow, such as CDGFC, a perfectly cylindrical with sides converging less, on the whole, towards of the corresponding portion of natural vein, and p-stream side of CED an inlet such as LACDBNL f corresponding efficiency as regards delivering or

supplying power—that is to say: a tube with sides havin requisite degree of convergence and curvature to afford tinuously, and without inducing superfluous back water, th quantity needed to render possible the whole transformati vein-momentum that the divergent receiver is capable of effe

In Mr. Herschel's Venturi meter it is a conical divergent tub sides of which are inclined to each other at an angle of 5°, eac forming an angle of 2½° with the longitudinal axis, that is us the down-stream side of the throat section $\overline{CED}$, while the si the convergent delivery tube or velocity generator which is at the up-stream side of the throat section $\overline{CED}$, are inclined angle of 21° to each other. The divergent tube is precisel same as that used by Mr. J. B. Francis, the noted Am hydraulic engineer, in his Lowell Experiments, as regard inclination of the sides to each other; but its length has limited to 23.6 diameters of the small base; it being take granted, presumably, that any addition in excess o said length would have no further beneficial influence o stream as regards transformation of momentum. The l of the divergent and convergent tubes of the small meter us Messrs. Coker and Strickland are not stated by them. Judging the longitudinal section given in their paper (Fig. 1), the formed by the sides of the divergent receiver of their meter a to have been more than 5 degrees and the length of this re proportionately greater than in Mr. Herschel's large meters; b sides of the convergent inlet tube are probably inclined only 21 degrees to each other, the same as in Mr. Herschel's mete though a greater degree of convergence is indicated in the Fig. 1.*

In all such divergent tubes, the momentum generated in the contracted vein projected through a simple orifice in a thin under the government of the molecular forces f and $.44f$, be transformed by the pressure exerted on the down-stream end vein by a liquid, or by a gas which is stemmed by it, with the ance of the lateral capillary attraction of the tubular envelope, action, called lateral communication of motion, converts a p the proportional molecular velocity of translation generated b force f into mass, while the proportional molecular velocity o

* In replying to points raised by the discussion of the paper "On the Measure Water by a small Venturi Meter," Dr. Coker remarked that the length of the upper the small McGill meter is 3 5-16 inches = 3.3125 inches, or 8.78 throat diameters. If th cone is a perfect conical frustum, viz., without any rounding off at the small base, as to be the case judging by the cut [Fig. 1] in the said paper, the inclination of the sides cone is double the angle of which the tangent is $\left(\frac{1.626 - 0.38}{2 \times 3.3125}\right) = 0{,}18.076$, viz., 2 x (10 22° - 18′. (See page 135, Part 1, "Transactions Can. Soc. C.E." for 1902, issued about No 1903.

to the action of the force .44*f* is correspondingly in-
divergent tube $\overline{CDGFC}$ apparently constitutes a sort
d counterpart of the convergent velocity generating
, or of the short frustum $\overline{AOBVUA}$ (within the reser-
yperbolic conoid assumed by a freely contracted vein
which is so proportioned as to be equivalent to the
, as regards discharging power under a given pres-
ould be possible to so shape such a divergent receiver
particular case, as to produce a stream capable of
aximum pressure smaller than, but having a definite
effective pressure in the reservoir R_1 by which the
ted, and producing a corresponding maximum velocity
aximum discharge.

solution of this complex problem in abeyance for the
consider the general case where a divergent receiver
red to hereafter as receiver G), having a length $\overline{EH} =$
gence $\overline{FDC}—\overline{CED} = 2ml'$, is added at the contracted
of an appropriate conoidal convergent inlet such as
h is nearly equivalent to the inlet $\overline{WZDCW}$, as
elocity generating and liquid supplying efficiency.
ne, in such case, as has been done in my pamphlet
contracted vein—that by the addition of the receiver
inlet $\overline{ABDCA}$, we cause the ethereal force .44*f* to be
tinuously by lateral communication, all along the
he contracted vein $\overline{ABDIJCA}$ between the points E
o become .44*jf*, where *j* is a factor greater than unity,
cular force *f* to be simultaneously diminished in a
manner between the same points, without taking
ion, for the present, the influence of the longitudinal
or profile of the tubular envelope of any particular
might be used; but taking for granted that such
es the implied theoretical condition of the transfor-
vein-momentum, consisting in the production of an
increase in the proportional velocity of translation
lecular force .44*f* and an equivalent decrease in the
velocity due to the force *f*. That is to say:
for granted for the moment, that all the receiv-
same length $\overline{EH}$ and the same end bases $\overline{LED}$ and
ly effective as regards transformation of vein-momen-
always they remain completely filled throughout by
dmitted through their convergent inlets, whether
envelopes be generated by the revolutions of zones

of triangles, zones of parabolas, zones of hyperbolas, or zo
any other kinds of curves about their respective axes of fig

In such case, considering that according to the theory of th
servation of energy, no part of the momentum generated by
of the effective pressure ($P_1 - P_2$) exerted by the liquid in rea
orifice $\overline{AOB}$ can go to loss, while the liquid particles impelle
pass from the plane of relative immobility or absolute rest
$\overline{H}$, through a convergent-divergent ajutage such as $\overline{ABDGF}$
total proportional velocity of molecular vein propagation, w
generated in the mass of the slice $\overline{AOB}$, during the periods
stream excursions of the liquid molecules between $\overline{UV}$ and $\overline{I}$
bear to the total proportional velocity of molecular vein for
generated in the same mass during the corresponding per
down-stream excursions of the liquid molecules very nea
ratio of:

$$\sqrt{.44s + .44x \cdot .44jx'} \text{ to } \left\{ \sqrt{.44s + x + x'} - \left(\sqrt{.44(s + x + jx')} - \sqrt{.44(s +} \right. \right.$$

so that if $\begin{bmatrix} \text{veloc} \\ \text{eff} \\ \text{orif} \\ \text{AOB} \end{bmatrix}$ denotes the velocity of efflux in the simple

$\overline{OAB}$, to which the conoidal inlet $\overline{ABDCA}$ correspon

and $\begin{bmatrix} \text{veloc} \\ \text{efflux} \\ \text{sect CED} \\ \text{inlet} \\ \text{ABDCA} \end{bmatrix}$ the velocity of efflux in the tip end

$\overline{CED}$, of the said convergent inlet; by making use
complete ajutage $\overline{ABDGFCA}$, or G, instead of only the
inlet, $\overline{ABDCA}$, the velocity in the plane of the said orifice,
increased very closely from

$$\begin{bmatrix} \text{veloc} \\ \text{eff} \\ \text{orif} \\ \text{AOB} \end{bmatrix} = \begin{bmatrix} \text{veloc} \\ \text{efflux} \\ \text{sect CED} \\ \text{inlet} \\ \text{ABDCA} \end{bmatrix} \times \frac{\sqrt{.44s + .44x}}{\sqrt{.44s + x}}$$

for the conoidal convergent inlet ABDCA when used by it

$$\begin{bmatrix} \text{veloc} \\ \text{eff} \\ \text{sect} \\ \text{AOB} \end{bmatrix} = \begin{bmatrix} \text{veloc} \\ \text{efflux} \\ \text{sect} \\ \text{CED} \\ \text{inlet} \\ \text{ABDCA} \end{bmatrix} \times \frac{\sqrt{.44(s + x + jx')}}{\sqrt{.44s + x + x'} - \left(\sqrt{.44(s + x + jx')} - \sqrt{.44(s} \right.}$$

for the entire convergent-divergent ajutage G. And re
now the constant numerical factor 0.44, adhered to, so fa

placing the law propagation of fluid conceives it to be, in a somewhat steadier ers, by the corresponding, actual variable face velocity of efflux in the plane, $\overline{AOB}$, through

, $\overline{ABDGFCA}$, of type G, by $\left[\begin{array}{c}\text{veloc}\\ \text{eff AOB}\\ \text{ajutage}\\ \text{ABDGFCA}\\ \text{type G}\end{array}\right]$ we

$$\times \frac{\sqrt{i_v(s+x+jx')}}{\left\{\sqrt{i_v s+x+x'}-\left(\sqrt{i_v(s+x+jx')}-\sqrt{i_v(s+x+x')}\right)\right\}} \qquad \binom{B}{G}$$

oiding, as much as possible, to bury out of principles underlying the subject, by the erec- unessential mathematical scaffolding over and those to which the late Mr. J. C. Trautwine, to refer as mathematical rubbish, in the pre- Pocket Book, we may assume, pending further convergent inlet $\overline{WZDCW}$ used in connection eiver $\overline{CDGFC}$, can deliver the same quantity ime, as a theoretically perfect conoidal inlet h is capable of supplying all the liquid re- n having the increased velocity of efflux

l by the said divergent receiver $\overline{DGFCD}$,

ly speaking, let us say that a conoidal con- $\overline{ABCDA}$ of length OE or x, which *is* properly nection with divergent receiver G, answers

ocities in section AOB between $\left[\begin{array}{c}\text{veloc}\\ \text{eff}\\ \text{orif}\\ \text{AOB}\end{array}\right]$ and

is actually found to be nearly the

placed by 0 in equation (B_G), that is to say: eiver $\overline{CDGFC}$ is removed altogether, and the ough the convergent inlet $\overline{WZDCW}$ or the $\overline{ABCDA}$, equation (B_G) becomes, as already

$$\begin{bmatrix}\text{veloc}\\ \text{eff AOB}\\ \text{inlet}\\ \text{ABDCA}\end{bmatrix} = \begin{bmatrix}\text{veloc}\\ \text{effux}\\ \text{sect CED}\\ \text{inlet}\\ \text{ABDCA}\end{bmatrix} \times \left[\frac{\sqrt{i_v(s+x)}}{\sqrt{i_v s+x}}\right]$$

We have moreover under such circumstances:

$$\frac{\begin{bmatrix}\text{veloc}\\ \text{eff AOB}\\ \text{inlet}\\ \text{ABDCA}\end{bmatrix}}{\begin{bmatrix}\text{veloc}\\ \text{eff AOB}\\ \text{ajutage}\\ \text{ABDGFCA}\\ \text{type G}\end{bmatrix}} = \frac{\begin{bmatrix}\text{veloc}\\ \text{eff CED}\\ \text{inlet}\\ \text{ABDCA}\end{bmatrix}}{\begin{bmatrix}\text{veloc}\\ \text{eff CED}\\ \text{ajutage}\\ \text{ABDGFCA}\\ \text{type G}\end{bmatrix}}.$$

Wherefore we can put:

$$\frac{\begin{bmatrix}\text{veloc}\\ \text{eff CED}\\ \text{inlet}\\ \text{ABDCA}\end{bmatrix}}{\begin{bmatrix}\text{veloc}\\ \text{eff CED}\\ \text{ajutage}\\ \text{ABDGFCA}\\ \text{type G}\end{bmatrix}} = \frac{(C_G)}{(B_G)} = \frac{\dfrac{\sqrt{i_v(s+x)}}{\sqrt{i_v s+x}}}{\dfrac{\sqrt{i_v(s+x+jx')}}{\sqrt{i_v s+x+x'} - \{\sqrt{i_v(s+x+jx')} - \sqrt{i_v(s+x+}}}$$

But, again, as according to the principle of the conservation o
no momentum can be lost, the sum of the successive ele
artificial increases in the velocity-factor of the vein-moment
cumulated at the section $\overline{CED}$ by lateral communication, du
passage of the vein through the divergent receiver from $\overline{C}$
$\overline{FGH}$, must therefore be counterbalanced by the sum of th
cessive elementary increases in the mass-factor of the vein-
tum accumulated at $\overline{FHG}$. That is to say: the proportional e
ary quantity of liquid moved bodily outward by virtue of
balanced pressure in reservoir R_1 acting during an incre
time, through the inlet $\overline{ABDCA}$, and which may be represe
$\overline{CE}^1$ or $\overline{DE}^2$ must bear to the proportional elementary qua
liquid moved by the same pressure, during an increment
through the ajutage ABDGFCA, which may be denoted by $\overline{F}$
inverse ratio which the velocity of translation generated
cross section $\overline{CED}$ of the complete ajutage $\overline{ABDGFCA}$, bears
velocity generated in the same cross section $\overline{CED}$ of t
$\overline{ABDCA}$, viz., we must have:

$$\overline{DE}^2 : \overline{FH}^2 :: \begin{bmatrix}\text{veloc.}\\ \text{eff. CED}\\ \text{inlet}\\ \text{ABDCA}\end{bmatrix} : \begin{bmatrix}\text{veloc.}\\ \text{eff. CED}\\ \text{ajutage}\\ \text{ABDGFCA}\\ \text{type G.}\end{bmatrix}$$

$$\frac{\begin{bmatrix}\text{veloc}\\ \text{eff CED}\\ \text{inlet}\\ \text{ABDCA}\end{bmatrix}}{\begin{bmatrix}\text{veloc}\\ \text{eff CED}\\ \text{ajutage}\\ \text{ABDGFCA}\\ \text{type G}\end{bmatrix}}$$

$$\left[\frac{\overline{DE}^2}{\overline{FH}^2} = \frac{r'^2}{(r'+mx')^2} = \frac{r'^2}{y'^2_G}\right]$$

the divergent receiver has such proportions and ion, that the limits of lateral communication are ped within it.

ng to equations (D_G), we must have the relations:

$$= \frac{\dfrac{\sqrt{i_v(s+x)}}{\sqrt{i_v s+x}}}{\dfrac{\sqrt{i_v(s+x+jx')}}{\sqrt{i_v s+x+x'} - \left\{\sqrt{i_v(s+x+jx')} - \sqrt{i_v(s+x+x')}\right\}}} \qquad (E_G)$$

the radius $\overline{DE}$, and m the tangent of half the angle the sides $\overline{DF}$ and $\overline{CG}$ (See Plate 14), whence we (F_G), which gives the value of the acceleration s of i_v, r', m, s, x and x', viz.:

$$\frac{\left(\sqrt{i_v s+x+x'}+\sqrt{i_v(s+x+x')}\right)^2(s+x)}{\left\{\sqrt{i_v(s+x)}+\left(\sqrt{i_v s+x}\right)\left(\dfrac{r'^2}{(r'+mx')^2}\right)\right\}^2} - \frac{s+x}{x'} \qquad (F_G)$$

bstitute this value of j for the symbol in the equa-

$$\frac{\begin{bmatrix}\text{veloc}\\ \text{eff DEC}\\ \text{ajutage}\\ \text{ABDGFCA}\\ \text{type G}\end{bmatrix}}{\sqrt{2gh}\begin{bmatrix}\text{coeff}\\ \text{eff DEC}\\ \text{inlet}\\ \text{ABDCA}\end{bmatrix}} = \frac{\sqrt{i_v(s+x+jx')}}{\sqrt{i_v(s+x+x')}} \qquad (G_G)$$

members represents equally well the throat velocity he section $\overline{DEC}$ of the receiver, or, as previously

explained, the ratio which the absolute number of fluid
considered as incompressible molecules, that pass in the un
through the orifice in the thin plate $\overline{AOB}$, as well as th
section of maximum contraction $\overline{DEC}$ of the inlet $\overline{ABDCA}$,
the number of such molecules that must flow under the sa
sure conditions and during the same time, through the corre
cross sections $\overline{AOB}$ and $\overline{DEC}$ of the compound pipe $\overline{ABCG}$
obtain, when the outer portion $\overline{CJIDC}$ of the freely c
auxiliary vein projected through the orifice $\overline{AOB}$, is rep
the divergent vein $\overline{CFGDC}$ having the same length,
formula (H_G) for the velocity in the throat $\overline{DEC}$ of an aju
as $\overline{ABDGFCA}$ of type G expressed in terms of h, i , r', m,
x', viz.:

$$\left[\begin{array}{c}\text{veloc}\\ \text{eff DEC}\\ \text{ajutage}\\ \text{ABDGFCA}\\ \text{type G}\end{array}\right] = \frac{\sqrt{2gh\left\{\dfrac{\left(\sqrt{i_v s+x+x'}+\sqrt{i_v(s+x+x')}\right)^2(s+x)}{\left(\sqrt{i_v(s+x)}+\sqrt{i_v s+x}\left(\dfrac{r'^2}{(r'+mx')^2}\right)\right)^2}\right\}}}{\sqrt{s+x+x'}} \times$$

where h stands for the total effective head of water on th
$\overline{AOB}$, or difference (P_1-P_2) between the pressures P_1 and P
obtain respectively in the reservoir R_1, at the up-stream
ajutage, $\overline{ABDGFCA}$, and at the down-stream end $\overline{FG}$ of
ajutage, and g for the acceleration of gravity.

From the above equations we deduce also, in general,
radius $R_0 = r' + mx'$, of the divergent receiver, $\overline{CDGFC}$ of
expressed in terms of i_v, j, i, s, x and x', and the ordinate
relation:

$$R'_G = y'_G = \frac{r'}{\left[\dfrac{\sqrt{\dfrac{\left\{\sqrt{i_v s+x+x'}+\sqrt{i_v(s+x+x')}\right\}^2(s+x)}{s+x+jx'}} - \sqrt{i_v(}}{\sqrt{i_v s+x}}\right.}$$

As already explained, the above nine equations from
(I_G) hold good for all divergent tubes of the same length, I

same end bases $\overline{CED}$ and $\overline{FHG}$, if we take for
ne vein-momentum is transformed as efficiently in
cone as in a frustum of a paraboloid, a frustum of
a frustum of a spheroid, or a frustum of a solid
ne revolution of the zone of any other curve about
re, besides those which correspond to the sections
entioned.

is conceivable that many divergent receivers such as
nvex sides and others with concave sides, are likely
lly the same momentum transforming efficiency as a
raight sides, provided the limits of the lateral com-
motion are not overstepped, it is obviously not
xpect that the molecular energy consumed in effect-
rmation of vein-momentum which corresponds to
t of the stream from $\overline{CED}$ to $\overline{FHG}$ in the distance
n precisely the same, no matter what may be the
ubular envelope used for the purpose, even though
within the limits of the lateral communication of
every point, nor that all combinations of con-
such as $\overline{WCDZW}$ and divergent tubes having the
and the same end bases $\overline{CED}$ and $\overline{FGH}$ as receiver
prove equally efficient as velocity generators
transformers under all possible pressure conditions,
ay be the conformation of the said tubes.

g investigations and computations (Cap. III and IV)
n by the writer, chiefly with a view of gaining an
geometrical relations of the interior shapes of the
es, the rates of increase or decrease of the ethereal
ponding to the periods of up-stream excursions of
e freely contracted vein, and the fluctuations in the
co-efficients, for some of the more elementary or
divergent receivers, as regards their conformation
nation of vein-momentum effected therein, and also
ng conoidal convergent inlets.

minations of numerical values of the variable quan-

velocity DEC tage GFCA] etc., obtaining under various conditions, which

de in this connection, are for convergent-divergent
same fundamental proportions and dimensions as the
turi meter used by Dr. Coker and Mr Strickland, as

nearly as the writer has been able to arrive at them from the
and diagrams given in their paper.

The proportions, dimensions, etc., of the essential parts
meter and other necessary data based on the same, whic
been adopted for the present purpose may be stated as follo

Throat diameter, $\overline{CD} = 2r' = 0.38$ inch $= 0.03166$ foot.

Approximate length OE of contracted vein inlet $\overline{ACDB}$
responding and equivalent, as regards velocity generating po
convergent mouth piece or inlet $\overline{WZDCW}$ of McGill Venturi
taken equal to $CD = l = 0.03166$ foot.

Approximate distance i s from plane of orifice, $\overline{AOB}$, to p
rest, $\overline{UPV} = i_v$ (0.15 inch $= 0.0125$ ft.)

Length of divergent receiver, $\overline{EH} = l' = (27 \times 0.38 = 10.26$
$= 0.855$ ft.)*

Throat radius, $\overline{EC} = r' = 0.19$ inch $= 0.1583$ ft. and
0.000250589 sq. ft.

Tangent of angle of inclination (3°—29′) of sides of di
cone to longitudinal axis of meter, $m' = 0.060725$.

Radius of large base, $\overline{FH} = r' + m'l' = (\frac{1.626 \text{ ins.}}{2} = 0.813 \text{ in.} = 0.067$

$$(r' + m'l')^2 = 0.004590062., \qquad \frac{r'^2}{(r' + m'l')^2} = 0.05459$$

$\overline{POE} = (s + l) = (0.55 \text{ in} = 0.04417 \text{ ft})$, $\overline{POEH} = (s + l + l') = (10.79 \text{ in.} = 0.8$
$\overline{OEH} = (l + l') = (10.64 \text{ in.} = 0.8867 \text{ ft.})$, $i_v = 0.40$, on an average.

On account of the convergent inlet, $\overline{WZBDCAW}$, of the
used in the experiments made at the McGill hydraulic obser
differing sensibly from the conoid which is equivalent, as r
delivery of liquid, to a freely contracted vein inlet of the
minimum diameter, $\overline{CED}$, the exact distance, $\overline{OE} = l$, betwe
small base $\overline{CED}$ of the former inlet and the orifice $\overline{AOB}$, in
plate, through which a natural free vein could be projected
a pressure such as $(P_1 - P_2)$, that would be nearly in the sam
dition, as regards the molecular propagation of motion when p
CD, as the stream projected from the said conical convergent
and the precise length of $0.44s = \overline{OP}$ in equations (A) to (I_0

* During the discussion of the paper "On the Measurement of Water by a smal
Meter" Dr. Coker remarked that the length of the lower cone of the small McGill
11 inches, viz., 28.94 throat diameters instead of only 27 as assumed by the writer. (
135, Part I, Transactions Can. Soc. Civ. Eng. for 1902, issued about November, 1903.)

d in some uncertainty; but judging by the conoid which joins the upper cone pro- roat in Mr. Herschel's meters, as com- tion or profile of the freely contracted vein, which is determined by the computed ordinates page 50, of the writer's pamphlet on the liquid dy referred to, we cannot err materially by put- $\overline{C}$)=(0.38 in. = 0.03166 ft.), and ($\overline{OP}$ = 0.44s)=(0.15 ove stated.

TYPICAL DIVERGENT RECEIVERS.

termined the generating curve of the divergent r envelope of an ajutage, $\overline{ABDGFCA}$, consisting t, $\overline{ABDCA}$, or its equivalent conical inlet, eceiver, $\overline{CDGFC}$, hereinafter referred to as being he same general proportions, above defined, as eter, but wherein the same simple transforma- um can be effected that was assumed to be in- viz., the transformation, which results from the of the ethereal force, $i_v f$, corresponding to the excursions of molecules in the free vein, at a ong the whole trajectory from E to H. The the acceleration factor, j_A, was computed by (F_G), with l and l' substituted for x and x' s found to be equal to 5.9426.

quations (G_G) and (I_G), the symbols by their above established, including 5,9426 for j_C, the of the generating curve of the tubular envelope ity co-efficients:

$$\Big] = \begin{bmatrix} \text{velocity} \\ \text{eff CED} \\ \text{ajutage} \\ \text{ABDGFCA} \\ \text{type A} \end{bmatrix} \div \sqrt{2gh} \begin{bmatrix} \text{coeff} \\ \text{veloc} \\ \text{eff CED} \\ \text{inlet} \\ \text{ABDCA} \end{bmatrix}$$

e tip end frusta of receiver, $\overline{CDGFC}$, of type A , and which have been numbered from 0 to 8, shown in:

TABLE A.

1	2	3	4	
Reference numbers for cross sections and corresponding tip end frusta of divergent tube or receiver $\overline{CDGFC}$ of type A (See Plate 16).	Argument x'. Distance throat $\overline{DEC}$ to cross section, and length of corresponding tip end frustum cut off from divergent receiver $\overline{CDGFC}$ of type A.	Rad. R'_A = ordinate $y'_A = r' + mx'$ of receiver $\overline{CDGFC}$ type A, at distance x' from throat $\overline{DEC}$, viz., radius of large base of corresponding tip end frustum	Throat velocity coefficient ajutage $\overline{ABDGFCA}$, type A. $= \dfrac{\left[\text{veloc eff CED ajutage ABDGFCA type A}\right]}{\sqrt{2gh}\left[\text{coeff eff CED inlet ABDCA}\right]}$, or proportional throat velocity v_A for each tip end frustum of divergent receiver $\overline{CDGFC}$ of type A.	j_A tion sity erea corr ing whic d u c thro by frust rece $\overline{C}$ type len acc to e (F_G)
SECTION	FEET	FEET		
0 at CED	0.000 000	0.015830	1.0000	5.
1	0.010 000	0.021458	1.3823	5.
2	0.020 000	0.025380	1.6859	5.
3	0.050 000	0.033432	1.9055	5.
4	0.100 000	0.041730	2.1038	5.
5	0.200 000	0.051140	2.2403	5.
6	0.500 000	0.062569	2.3542	5.
7 at FGH	0.855 000	0.067750	2.3873	5.
8	1.100 000	0.069688	2.3983	5.

On Plate 16 the generating curve of the inner surface of the
gent receiver of type A is shown by a full line, marked A, a
geometrical loci of the rates of increase j_A of the force i
the corresponding proportional velocities v_A which obtain

throat, viz., the throat velocity co-efficients $\left[\text{coeffic eff CED ajutage ABDGFCA type A}\right]$ when

as ordinates corresponding to the distances x' used as abscissa
indicated respectively by a right line parallel to the axis of X m
A_j and a curve marked A_v.

ing the generating curves of the tubular envelopes of
ple divergent receivers, $\overline{CDGFC}$ investigated, and the
convergent inlets, $\overline{mnDCm}$, the same scale was, of
r both the abscissas and the ordinates. The units
hown on the lower diagram (Plate 16) represents
t of the small McGill meter, 1.0474 feet of the meter
erschel at Holyoke in 1887, with a one-foot main,
at diameters in general.

of the computed co-ordinates which determine the
es of the inner surfaces of the said conoidal divergent
tubes, are respectively at the centres E and e of the
, or bases $\overline{CED}$ and $\overline{ced}$ of these tubes, where the
of natural vein-momentum effected by them com-

hical representation of the variations of the ethereal
nd the corresponding proportional throat velocities v,
ty co-efficients, the unit for the ordinates was short-
5 to one throat diameter, chiefly with a view of re-
ram to a more convenient size for reproduction and

s of these j and v curves have been plotted, from an
s moved a short distance up from the axis $\overline{EX}$ of the
es, with the object of keeping the two sets of curves
stinct; the same axes of ordinates were, of course,
the curves.

t, $\overline{DEC}$, of the receiver of type A, as above determ-
iverge from the longitudinal axis $\overline{OX}$, over 30 degrees
ul if, under ordinary circumstances, a receiver of the
imed could be kept running full even for efflux under
ds; but of course the general proportions of the
velope could be altered so as to ensure this, viz.,
it.

er determined, as shown hereunder, the ordinates
e generating curve of the tubular envelope and the
hroat velocity co-efficients $\left[\begin{array}{c}\text{coeffic}\\ \text{eff CED}\\ \text{ajutage}\\ \text{ABDGFCA}\\ \text{type B}\end{array}\right]$ for a receiver,
type called B, having the same length and the same
of the sides as that of the McGill meter, but where-
portional velocity denoted by $\sqrt{i_1(s+x+x')}$ which is
g the up-stream periods of freely contracted vein

having a length $(s+x+x')$, is uniformly augmented so as to
equal to $\sqrt{i_v(s+x+x')}+qx'$ at the distance x' from the sm
CED, while the total proportional velocity represented by $\sqrt{i_v}$
which is generated during the periods of down-stream excurs
molecules is correspondingly diminished, viz., to: $\sqrt{i_v s+x+x'}$

Under such conditions, equation (B_G) becomes for a rec
type B:

$$\begin{bmatrix} \text{veloc} \\ \text{eff AOB} \\ \text{a}\cancel{\text{t}}\text{tage} \\ \text{ABDG}\cancel{\text{F}}\text{CA} \\ \text{type B.} \end{bmatrix} = \begin{bmatrix} \text{veloc} \\ \text{efflux} \\ \text{sect. CED} \\ \text{inlet} \\ \text{ABDCA} \end{bmatrix} \times \frac{\sqrt{i_v(s+x+x')}+qx'}{\sqrt{i_v s+x+x'}-qx'}$$

and equation (E_G) becomes :

$$\frac{r'^2}{v'^2_B} = \frac{r'^2}{(r'+mx')^2} = \frac{\dfrac{\sqrt{i_v s+x+x'}-qx'}{\sqrt{i_v(s+x+x')}+qx'}}{\dfrac{\sqrt{i_v s+x}}{\sqrt{i_v(s+x)}}} \qquad (\ \ \ \

$$\frac{\left.\begin{matrix}\text{coeff}\\ \text{eff DEC}\\ \text{inlet}\\ \text{ABDCA}\end{matrix}\right]}{\left.\begin{matrix}\text{loc}\\ \text{DEC}\\ \text{age}\\ \text{GFCA}\\ \text{e B}\end{matrix}\right]} = \frac{\sqrt{i_v(s+l+x')}+qx'}{\sqrt{i_v(s+l+x')}} \qquad (G_B)$$

ate $y'_B = R'_B = (r'+mx')$ of the generating curve
e of the receiver of type B and radius R'_B, of
ss section of this receiver:

$$rx') = r' \times \sqrt{\frac{\left(\frac{\sqrt{i_v s+l}}{\sqrt{i_v(s+l)}}\right)\left(\sqrt{i_v(s+l+x')}+qx'\right)}{\sqrt{i_v s+l+x'}-qx'}} \qquad (I_B)$$

ation (G_B) with (G_G) and put :

$$(s+l+x')+qx' = \sqrt{i_v\,(s+l+j_B x')}$$

rrow limits, for the relative intensity of the
roat, after the stream has passed over a dis-
all base, CED:

$$= \frac{\left(\sqrt{i_v(s+l+x')}+qx'\right)^2 - i_v(s+l)}{i_v x'} \qquad (F'_B)$$

DGFC, of type B, having the same fundamental
f the McGill meter, the numerical value of the
be 0.9728, and the ordinates of the generating
, which have been computed, together with the
velocity co-efficients and the factors j indi-
the relative intensities of the force corres-
h is induced in the throat after the vein has
' from CED, are as shown in:—

TABLE B.

1	2	3	4
Reference numbers for cross sections and corresponding tip end frusta of divergent receiver $\overline{CDGFC}$ of type B wherein q is uniformly equal to 0.9728.	Argument x' Distance throat $\overline{CED}$ to cross section, and length of corresponding tip end frustum cut off divergent tube $\overline{CDGFC}$ of type B.	Radius $R'_B = y'_B = (r' + mx')$ of cross section of receiver B at distance x' from throat at $\overline{CED}$, viz. radius of base of corresponding tip end frustum.	Throat velocity coefficient ajutage $\overline{ABDGFCA}$, type B. $= \dfrac{\left[\text{veloc eff CED ajutage ABDGFCA type B}\right]}{\sqrt{2gh}\left[\text{coeff eff CED inlet ABDC}\right]}$ or, proportional throat velocity v_B for each tip end frustum of divergent tube CDGFC of type B.
SECTION	FEET	FEET	
0 at CED	0.000 000	0.015830	1.0000
1	0.010 000	0.016563	1.0661
2	0.020 000	0.017225	1.1214
3	0.050 000	0.018876	1.2503
4	0.100 000	0.021140	1.4050
5	0.200 000	0.025160	1.6224
6	0.500 000	0.035360	2.0424
7	0.700 000	0.049960	2.2481
8 at FHG	0.855 000	0.067750	2.3868
9	0.900 000	0.077140	2.4251
10	1.000 000	0.115650	2.5054
11	1.092 160	∞	2.5755

The generating curve of the receiver, $\overline{CDGFC}$, of type B, geometrical loci of the proportional intensities j_B of the force corresponding to $i_v f$, which obtain during the period stream excursions of molecules, and of the throat velocity

ients $\left[\text{coeff eff CED ajutage ABDGFCA type B.}\right]$ are indicated on Plate 16, in the same

for the receiver of type A.

By comparing the results entered in columns 2 and 3 of with those entered in the corresponding columns of Table D

d the corresponding geometrical loci which are
e marked D on Plate 16, it will be seen that the
receiver B is slightly convex to the longitudinal
.080 ft. of the McGill meter = 25.27 throat dia-
oncave thence to the lower base $\overline{FG}$.

king as a basis of computation, either a uniform
eal force $i_v f$ which acts during the periods of
sions of the liquid particles in the freely con-
s from $i_v f$ to $ji_v f$, or an increase in the total
corresponding to the said periods, such as from
$\sqrt{i_v(s + x + x')} + qx'$, or from $\sqrt{i_v(s + x + x')}$
$(s + x + x')$, and determining the curves which,
t their respective axes of figure, sweep out the
eceivers that afford the desired variation either
ce $i_v f$, or in the total proportional velocity of
vein which is represented by $\sqrt{i_v(s+x+x')}$, we
reverse train of reasoning, take up a divergent
nite shape and proportions, and determine the
of the transformations of vein-momentum in-
the values of the resulting throat velocity

, the writer undertook to make such determina-
with a trumpet mouth, hereinafter referred to as
interior surface of which is determined by the
$\overline{CEHFTC}$, of a kind of cubical hyperbola, about
o-inciding with the axis $\overline{OX}$ of the theoretical
ein formed in the orifice $\overline{AOB}$. The writer
referred to rectangular axes of co-ordinates, EX
olic curve generating the conoidal frustum which
C, is determined by the equation:

$$R'^2_C = (r' + mx')^2 = \frac{r'^2\,(l' + p)}{(l' + p - x')\,c} \qquad (K_C)$$

onstant distance $\overline{HK}$ and c a constant arbitrary
esenting, as heretofore, the radius $\overline{ED}$, l', the
he receiver of type C and m', in general, the tan-
divergence corresponding to x', which is equal

Putting $x' = l'$ and $m' = m'_0 = \dfrac{\overline{FH} - \overline{CE}}{\overline{EH}}$ in equation (K_C obtain:

$$(r' + m'_0 l')^2 = \frac{r'^2(l' + p)}{pc}, \text{ whence we deduce:}$$

$$p = \frac{r'^2 l'}{(r' + m'_0 l)^2 c - r'^2} \qquad (L_C$$

an equation in which all the symbols represent known quantit

By following a train of reasoning similar to that which lea series of equations (I_G) we obtain equations :

$$y_C = R'^2_C = (r' + m'x')^2 = \frac{r'^2 (l' + p)}{(l' + p - x')c} =$$

$$r' \div \left[\frac{\sqrt{\dfrac{\left\{\sqrt{i_v s + x + x'} + \sqrt{i_v(s + x + x')}\right\}^2 (s + x)}{s + x + j_C x'}} - \sqrt{i_v(s + x}}{\sqrt{i_v s + x}} \right.$$

$$(I_$$

and putting $c = 1$ in equation (I_G), reducing; etc., we arriv

$$\frac{(l' + p)}{(l' + p - x')} = \frac{(\sqrt{i_v s + x})(\sqrt{s + x + j_C x'})}{\sqrt{\left\{\sqrt{i_v s + x + x'} + \sqrt{i_v(s + x + x')}\right\}^2 (s + x) - (\sqrt{s + x + jx'})(\sqrt{i_v}}}$$

$$(I'$$

and at :

$$\left(\sqrt{s + x + j_C x'}\right)\left\{\sqrt{i_v s + x} + \left(\sqrt{i_v(s + x)}\right)\left(\frac{l' + p}{l' + p - x'}\right)\right\} =$$

$$= \frac{l' + p}{l' + p - x'} \sqrt{\left\{\sqrt{i_v s + x + x'} \sqrt{i_v(s + x + x')}\right\}^2 (}$$

$$(I''_C$$

whence we deduce the value of the acceleration factor j_C, wh determined approximately in terms of i_v, s, l', p, x and x' b expression:

$$\frac{{}^{2}\left(\sqrt{i_v s+x+x'}+\sqrt{i_v(s+x+x')}\right)^2(s+x)}{\overline{i_v s+x}+\left(\sqrt{i_v(s+x)}\right)\left(\frac{l'+p}{l'+p-x'}\right)\Big\}^2} - \frac{s+x}{x'} \qquad (F_c)$$

determining the throat velocity. co-efficients of

$$\left[\begin{matrix}\text{veloc}\\ \text{eff CED}\\ \text{ajutage}\\ \text{BDGFCA}\\ \text{of type C}\end{matrix}\right] \Bigg/ \left[\begin{matrix}\text{coeff}\\ \text{eff CED}\\ \text{inlet}\\ \text{ABDCA}\end{matrix}\right] = 1 \Bigg] = \frac{\sqrt{i_v(s+l+j_c x')}}{\sqrt{i_v(s+l+x')}} \qquad (G_c)$$

niformly at 0.40, as heretofore, it is found that -shaped receiver, of type C, having the same same end bases $\overline{DEC}$ and $\overline{FHC}$ as the McGill

$$\frac{r'^2 l'}{(r'+m'_0 l')^2 - r'^2} = 0.049373 \qquad (P_c)\,.$$

acceleration factor, j_c, the ordinates $y'_c = R'_c$

fficients $\left[\begin{matrix}\text{coeff}\\ \text{eff CED}\\ \text{ajutage}\\ \text{ABDGFCA}\\ \text{of type C}\end{matrix}\right]$ corresponding to the

for which these quantities were computed, the ers of types A and B, are entered in:—

TABLE C.

1	2	3	4	5
Reference numbers for cross sections and corresponding tip end frusta of the receiver $\overline{CDGFC}$ of type C, wherein the arbitrary constants c and p are uniformly equal to 1 and 0.049373 respectively	Argument x'. Length of each tip end frustum cut off from the hyperboloidal divergent receiver $\overline{CDGFC}$ of type C.	$R'_c = y'_c = (r' + mx')$ Radius of each cross section of hyperboloidal divergent receiver $\overline{CDGFC}$ of type C, at distance x' from throat $\overline{CED}$	Throat velocity coefficient of ajutage $\overline{ABDGFCA}$, type C. $\left[\frac{\text{veloc eff CED ajutage ABDGFCA of type C}}{\sqrt{2gh}\left(\left[\text{coeff eff CED inlet ABDCA}\right] = 1\right)}\right]$ or proportional throat velocity v_c, for each tip end frustum of receiver $\overline{CDGFC}$ of type C	j_c P tiona creas tensi the et force respo to $i_v f$, is indu throa by ea end fr of le x' c from verge ceive $\overline{C}$ of typ
SECTION	FEET	FEET		
0 at $\overline{CED}$	0.000 000	0.015830	1.0000	1.
1	0.200 000	0.017935	1.1837	1.
2	0.300 000	0.019364	1.3063	1.
3	0.400 000	0.021200	1.4243	2.
4	0.500 000	0.023672	1.5629	2.
5	0.600 000	0.027285	1.73206	3.
6	0.700 000	0.033280	1.9411	3.
7	0.750 000	0.038330	2.1568	4.
8	0.800 000	0.046590	2.2075	5.
9	0.830 000	0.055223	2.3018	5.
10 at $\overline{FHG}$	0.855 000	0.067750	2.3867	5.
11	0.875 000	0.087838	2.4600	6.
12	0.895 000	0.155461	7.0854	52.
13	0.904 373	∞	∞	∞

40. With the aid of equations (F_G) and (G_G) (see page 27 writer computed the values of the acceleration factor j_D a done in the cases of j_B and j_C, and also the throat veloci efficients:

$$\frac{\begin{bmatrix}\text{veloc}\\ \text{eff } \overline{\text{CED}}\\ \text{ajutage}\\ \text{ABDGFCA}\\ \text{of type D}\end{bmatrix}}{\sqrt{2gh}\left(\begin{bmatrix}\text{coeff}\\ \text{eff } \overline{\text{CED}}\\ \text{inlet}\\ \text{ABDCA}\end{bmatrix} = 1\right)}$$

receiver D with straight sides, which was used in nents made by Dr. Coker and Mr. Strickland in e proportions of the Venturi meter experimented lemen, as above defined, to be correct, and taking 4, the same as for all the other tubes considered, found to be as shown in

TABLE D.

	3	4	5
ent gth end of di- re-	$R'_D = y'_D = (r' + mx')$. Radius of conical receiver $\overline{\text{CDGFC}}$ or D, at distance x' from throat $\overline{\text{CED}}$.	Throat velocity coefficient ajutage $\overline{\text{ABDGFCA}}$ of type D: $= \frac{\begin{bmatrix}\text{veloc}\\ \text{eff } \overline{\text{CED}}\\ \text{ajutage}\\ \text{ABDGFCA}\\ \text{type D}\end{bmatrix}}{\sqrt{2gh}\left(\begin{bmatrix}\text{coeff}\\ \text{eff } \overline{\text{CED}}\\ \text{inlet}\\ \text{ABDCA}\end{bmatrix} = 1\right)}$, or proportional throat velocity v_D, for each tip end frustum of conical CDGFC or D.	j_D Factor showing proportional increased intensity of ethereal force corresponding to $t_v f$, induced in throat $\overline{\text{CED}}$ of receiver $\overline{\text{CDGFC}}$ type D, by tip end frustum of length x'
FC to- rg- r'.	FEET		
00	0.015 830	1.000 000	1.000 000
00	0.017 044	1.109 040	1.734 250
00	0.018 866	1.265 500	2.057 510
00	0.021 902	1.449 140	2.585 960
00	0.027 975	1.748 720	3.512 550
00	0.040 120	2.098 420	4.778 830
00	0.052 265	2.271 830	5.467 283
00	0.067 750	2.387 200	5.941 640
00	0.070 482	2.400 597	5.996 624
00	0.082 628	2.444 656	6.187 541

The geometrical loci of the throat velocity co-efficients $\left[\begin{array}{c}\text{coe}\\ \text{eff}\\ \text{ajut}\\ \text{ABDG}\\ \text{type}\end{array}\right.$

and of the factors f_D are shown on Plate 15, the same as fo
other receivers.

5o. The writer determined the generating curve of the inne
face of a receiver called E, wherein the total proportional ve
represented by $\sqrt{i_v(s+x+x')}$, which corresponds to the peri
up-stream excursions of molecules in a freely contracted
$\overline{\text{ABDIJA}}$, could be uniformly augmented along the trajectory
ing from E to H so as to become at every point equ
$\sqrt{i_v(s+x+x')}$, and wherein the total proportional velocity
rated during the periods of the down-stream excursions o
molecules simultaneously diminished to:

$$\left\{\sqrt{i_v s+x+x'}-\left(n_E\sqrt{i_v(s+x+x')}-\sqrt{i_v(s+x+x')}\right)\right\}$$

n_E being a number greater than 1, depending on the degr
divergence of the sides of the receiver

Equation (B_G) becomes in this instance changed to :

$$\left[\begin{array}{c}\text{veloc}\\ \text{infl AOB}\\ \text{ajutage}\\ \hline \text{ABDGFCA}\\ \text{type E}\end{array}\right]=\left[\begin{array}{c}\text{veloc}\\ \text{eff CED}\\ \text{conv inlet}\\ \hline \text{ABDCA}\end{array}\right]\times\frac{n_E\sqrt{i_v(s+x+x')}}{\sqrt{i_v s+x+x'}-\left(n_E\sqrt{i_v(s+x+x')}-\sqrt{i_v(s+x}\right.}$$

and the series of equations (E_G) is changed to :

$$\frac{r'^2}{y'^2_E}=\frac{r'^2}{R'^2_E}=\frac{r'^2}{(r'+m_E x')^2}=\frac{\sqrt{i_v s+l+x'}+\sqrt{i_v(s+l+x')}-n_E\sqrt{i_v(s+l+}}{n_E\left\{\left(\frac{\sqrt{i_v s+l}}{\sqrt{i_v(s+l)}}\right)\left(\sqrt{i_v(s+l+x')}\right)\right\}}$$

x being replaced by l, wherefore we have in general, the same
equations (G_G), (G_B), (G_C) the relations :

$$\frac{\left[\begin{array}{c}\text{veloc}\\ \text{eff CED}\\ \text{ajutage}\\ \text{ABDGFCA}\\ \text{type E}\end{array}\right]}{\sqrt{2gh}\left[\begin{array}{c}\text{coeff}\\ \text{eff CED}\\ \text{inlet}\\ \text{ABDCA}\end{array}\right]}=\frac{n_E\sqrt{i_v(s+l+x')}}{\sqrt{i_v(s+l+x')}}$$

$$\frac{r'^2 n_E \left(\frac{\sqrt{i_v s+l}}{\sqrt{i_v(s+l)}}\right) \sqrt{i_v(s+l+x')}}{\sqrt{i_v s+l+x'}+\sqrt{i_v(s+l+x')}-n_E\sqrt{i_v(s+l+x')}} \qquad (I_E)$$

E_E) and (I_E) we deduce, in general, for n'_E m_E, l and x', the expression:

$$\frac{\sqrt{i_v s+l+x'}+\sqrt{i_v(s+l+x')}}{{}^{2}\left(\frac{\sqrt{i_v s+l}}{\sqrt{i_v(s+l)}}\right)+1\Big\}\sqrt{i_v(s+l+x')}} \qquad (J_E)$$

$_E$) with (G_G), page 271, we see that we can put:

$$\sqrt{i_v(s+l+x')}=\sqrt{i_v(s+l+j_E x')}$$

or the acceleration factor j_E, within narrow :

$$j_E=\frac{n_E^2(s+l+x')-(s+l)}{x'} \qquad (F_E)$$

n equations (G_E) and (J_E), the variable quan- and m'_E respectively, we obtain, for determin- meter.

$$\frac{\sqrt{i_v s+l+l'}+\sqrt{i_v(s+l+l')}}{{}^{2}\left(\frac{\sqrt{i_v s+l}}{\sqrt{i_v(s+l)}}\right)+1\Big\}\sqrt{i_v(s+l+l')}} \qquad (J'_E)$$

the throat velocity co-efficient, the formula :

$$\frac{\left[\begin{array}{c}\text{veloc}\\ \text{eff CED}\\ \text{ajutage}\\ \text{ABDNGFMCA}\\ \text{type E'}\end{array}\right]}{\sqrt{2gh}\left[\begin{array}{c}\text{coeff}\\ \text{eff CED}\\ \text{inlet}\\ \text{ABDCA}\end{array}\right]} = \frac{n'_K\sqrt{i_v(s+l+l')}}{\sqrt{i_v(s+l+l')}}$$

For the McGill meter equation (J'_E) gives $n'_E = 2{,}3867$, the as for the other receivers with sides having a total divergence to $2r'm'l'$, or ($\overline{FG}$—$\overline{CD}$).

According to equation (B_E) the velocity of translation in section $\overline{AOB}$ of ajutage ABDNGFMUA with receiver $\overline{CDNGF}$ E, and hence also the velocity in its throat CED, becomes evi a maximum when the denominator of the fraction in the member of the said equation is equal to 0, in which case we

$$n_E = 1 + \frac{\sqrt{i_v s + x + x'}}{\sqrt{i_v(s+x+x')}}$$

But when $x + x'$ is very long in comparison to s, as us all convergent-divergent ajutages such as the Venturi mete can put very nearly:

$$\sqrt{i_v s + x + x'} = \sqrt{s + x + x}$$

whence we deduce:

$$n_E = 1 + \frac{1}{\sqrt{i_v}}$$

For $i_v = 0.40$ this formula gives 2.5652 for the maximum t tical value of the throat velocity co-efficient n_E.

In his Lowell experiments, J. B. Francis, the noted Am hydraulic engineer, obtained for efflux under water with an eff head of 1.18 ft. through a conical divergent tube 0.102 diameter at the tip end, 30 small diameters and 14¼ mean diar long and having straight sides inclined 5° 1′ to each other, a mum throat velocity co-efficient of 2.43, when the tube was merged 1.57 feet.

With the aid of equations (F_E) (G_E) (I_E) and (J_1), w the characteristic ordinates $y'_E = R'_E = r' + m'_E x'$ of the ge ing curve of the receiver, CDGFC of type E, viz., $\overline{CDNGFM}$ nine abscissas x' together with the proportional acceleration

corresponding to $i_v f$ and the accompanying
ocity co-efficients, which are given in

TABLE E.

3	4	5	6
rdinate $_E = R'_E =$ $_E x'$ of ross section of receiver CDGFC type E, t distance x' from throat section MCEDN	n'_E Throat velocity coefficient at CED. $\left[\begin{matrix}\text{coeff eff}\\\text{at CED}\\\text{ajutage}\\\text{ABDGFCA}\\\text{type E}\end{matrix}\right] = \dfrac{\left[\begin{matrix}\text{vel eff}\\\text{at CED}\\\text{ajutage}\\\text{ABDGFCA}\\\text{type E}\end{matrix}\right]}{\sqrt{2gh}\left[\begin{matrix}\text{coeff}\\\text{eff at}\\\text{CED}\\\text{conv}\\\text{inlet}\\\text{ABDCA}\end{matrix}\right]}$ or proportional throat velocity v_E for each but end frustum of length x'.	Mouth velocity coefficients: $\left[\begin{matrix}\text{coeff}\\\text{eff at}\\\text{CED}\\\text{ajutage}\\\text{ABDG}\\\text{FCA}\\\text{type E}\end{matrix}\right] \times \dfrac{r'^2}{R'^2_E}$ for each butt end frustum of length x'.	j_E Proportional intensity of ethereal force corresponding to $i_v f$ induced in butt end frustum of receiver CDGFC type E of length x' according to equation F_E), when $i'_E =$ 2.3867
FEET			
∞	2.3867	0.000 000	
0.126 400	2.3867	0.037 411	∞
0.102 900	2.3867	0.056 477	26.440057
0.093 360	2.3867	0.068 618	18.055397
0.081 810	2.3867	0.089 346	10.600141
0.075 170	2.3867	0.105 873	7.770709
0.073 330	2.3867	0.117 964	6.733523
0.068 510	2.3867	0.127 114	6.111211
0.067 750	2.3867	0.130 385	5.939187
0.067 456	2.3867	0.131 357	5.884916

rve of the inner surface of the tubular envelope
hich would be suitable for increasing the pro-
$\sqrt{(s+x+x')}$ corresponding to the periods of up-
molecules in the freely contracted vein, uni-
times, if that was practicable, is shown on
e, marked E, the same as the generating curves
d C. This abrupt transformation of the vein-

momentum of the freely contracted vein $\overline{ABDCA}$ is, howeve
dently impracticable; for at its exit from the convergent i
$\overline{DEC}$, the stream, while flowing in the direction, $\overline{EH}$, would su
ly have to expand or be artifically enlarged so as to occupy a s
having a radius of 0.126400 ft., and hence cover in an infinitely
space of time, an area 63.7937 times as great as that of cross s
DEC.

Yet it cannot be gainsayed that each one of the imaginary
gent receivers $\overline{CDNMC}$, $\overline{CD.1.1'C}$, $\overline{CD.2.2'C}$, $\overline{CD.5.5'C}$, $\overline{CD11'C}$, C
$\overline{CD44'C}$.....$\overline{CDGFC}$, the butt end bases of which are cros
tions of the conoidal receiver E—can theoretically produce by
formation of vein-momentum, a velocity of translation in its
section $\overline{CED}$ which is equal to $(n'_E = 2.3867 \sqrt{2g(P_1 - P_2)}$—
is evident no loss of momentum or of energy can occur at an
during the progress of the vein formed in tube E by virtue
pressure $(P_1 - P_2)$, from E to H.

The writer's explanation of the meaning of this
matical virtual transformation of vein-momentum by
communication of motion in receiver E with conv
sides, is as follows: When the receiver E is use
itself in connection with reservoirs R_1 and R_2, not
has the continuous liquid vein formed in it from E to H by vir
the pressure $(P_1 - P_2)$, to acquire, the same as all freely cont
circular liquid veins, at its exit from reservoir R_1 at the bu
$\overline{MEN}$—successively the momentums which can produce in t
ends $\overline{NM}$, $\overline{.1.1'}$, $\overline{.2.2'}$, $\overline{.5.5'}$, $\overline{11'}$, $\overline{22'}$, $\overline{44'}$.....and $\overline{FG}$, vel
varying between the limits of $\sqrt{2i_v g(P_1 - P_2)}$ and $\sqrt{2g P_1}$
but at the same time there must gradually be stored up in t
ceiver, liquid under pressure all along from E to H, in such a
ner as to afford the additional energy required for producing
whole of the enveloped imaginary divergent tubes of the above
taken separately—an increase in the theoretical velocity d
$(P_1 - P_2)$ obtaining in the tip end of the inlet $\overline{ABDCA}$ or $\overline{C}$
to each one of these tubes,—in the ratio of 1 to 2,3867. That
say: while the said vein is flowing from E to H in virtue
pressure $P_1 - P_2$, there must be continuously accumulated a
extra energy in the shape of liquid under pressure, which is re
for increasing 2.3867 times it own veloc ty of translation throu
clear tube E generated by the said pressure $(P_1 - P_2)$. So that
an enlarged divergent receiver having the same proportions
hence the same momentum transforming efficiency (or very
so) as receiver $\overline{CDGFC}$—viz., a divergent tube capable of incre
2.3867 times the velocity at its small base $\overline{FHG}$—is added at t

ıbe E, this tube constitutes an inlet capable of supply of liquid needed to satisfy the draught ion of the said large divergent receiver between the whole of the energy accumulated in the t back under pressure being then brought into purpose as the complement that possessed by The virtual transformation of vein-momentum ver E with convergent sides is in reality the l action of the actual transformation of vein-l communication of motion that can be effected iver with divergent sides just supposed to be een the reservoirs R_1 and R_2.

ı the ethereal movements of liquid molecules ıe storage of liquid under pressure at the up-ınvergent tube E just pointed out, are here tak-ɔsite direction of the changes in such movements he stemming of liquid under pressure at the a divergent tube resulting from the transforma-tum by lateral communication of motion. In er surmises, the orbits of the excursions of the e contracted or restricted and their movements ingly in rapidity.

he results entered in column 5 of table E, that a ɔcity equal to but 0.037411 $\sqrt{2g(P_1-P_2)}$ in the s sufficient to supply the volume of liquid that a continuous vein flowing in the divergent re-a head (P_1-P_2)—and that the corresponding ıs simultaneously in the section $\overline{FHG}$ is 0.138385

l enveloping receiver $\overline{mnDCm}$ of the same pro-with its tip end base, equal to $\overline{CED}$ instead of be designated as tube E_1, the velocity would, in $\left(\frac{FH^2}{CE^2}\right) = 18{,}31688$ times greater than that in t the draught induced by the divergent receiver atisfied, and in the section $\overline{mn}$ of receiver E_1 $\overline{N}$ in receiver E, the velocity co-efficient would 0.037411 × 18.316688 or 0.68524561, and the 8524561 $\sqrt{2g\,(P_1-P_2)}$. For supplying the in-ıuid needed to create and keep up this increased eceiver E_1, the quantity of liquid under back luring the formation of vein $\overline{mnDCm}$ from e to

E is brought into requisition and drawn upon until entire
hausted, as already stated.

It is thus readily seen, that a uniform transformation c
momentum similar to that which is called for in the larg
vergent enveloping tube E or $\overline{MNGFM}$, may be effected w
having to resort to an abrupt expansion of the stream at it
from the conoidal inlet at $\overline{DEC}$, as required in receiver E, by
a conoidal convergent tube $\overline{mnDCm}$ or E_1, similar to E, havin
for its small base instead of $\overline{FGH}$, and for generating curve th
termined by equation (I_E); n_E being taken equal to 2.3867 as
and r', s and l being replaced by $\frac{r'}{k}$, $\frac{s}{k}$ and $\frac{l}{k}$ respectively,
$k = \frac{\overline{FGH}}{\overline{CED}}$, provided always an artificial draught in the directio
be created at the lower end of the reduced enveloping tu
corresponding to the multiple total proportional ve
$n_E\sqrt{i_v(s + l + x')}$, which is induced in the said convergen
during the periods of up-stream excursions of molecules,
draught such as that which results from the addition of a div
receiver, $\overline{CDGFC}$, to tube E_1 at its small base, $\overline{CED}$.

If besides substituting $\frac{r}{k}$ for r, $\frac{s}{k}$ for s and $\frac{l}{k}$ for l in eq
($I_{\ }$), we replace x' by l'_1, the total length Ee of tube E
responding to $\overline{EH} = l'$ in tube E, we obtain for the inlet tu
the relation:

$$\overline{DE} = r' = \frac{r'}{k}\sqrt{\frac{n\left(\frac{\sqrt{i_v s + l}}{k}\right)\sqrt{i_v\left(\frac{s+l}{k}+l'_1\right)}}{\sqrt{i_v\,\frac{s}{k}+\frac{l}{k}+l'_1}+(1-n)\sqrt{i_v\left(\frac{s+l}{k}+l'_1\right)}}}$$

whence, dividing both members of this equation by r', we ob

$$\sqrt{\frac{\frac{n}{k_2}\left(\frac{\sqrt{i_v s+l}}{\sqrt{i_v(s+l)}}\right)\sqrt{i_v\left(\frac{s+l}{k}+l'^1\right)}}{\sqrt{i_v\left(\frac{s}{k}\right)+\frac{l}{k}+l'_1}+(1-n)\sqrt{i_v\left(\frac{s+l}{k}+l'_1\right)}}} = 1 \qquad ($$

and solving this equation in reference to l'_1, we obtain:

$$\frac{\ldots l\Big)\left\{\frac{n}{k^2}\left(\frac{\sqrt{i_v s+l}}{\sqrt{i_v(s+l)}}\right)-(1-n)\right\}^2-\left(\frac{i_v s+l}{k}\right)}{\ldots i_v\left\{\frac{n}{k^2}\left(\frac{\sqrt{i_v s+l}}{\sqrt{i_v(s+l)}}\right)-(1-n)\right\}^2} \qquad (L_{E1})$$

general, for n_{E1}, in terms of i_v, s, r', m_{E1}, l, k sion:

$$\frac{\ldots\sqrt{\frac{i_v s+l}{k}+x'_1}+\sqrt{i_v\left(\frac{s+l}{k}+x'_1\right)}}{\ldots\frac{\ldots r'\Big)^2}{\ldots n_{E1}x'\Big)^2}\left(\frac{\sqrt{\frac{i_v s+l}{k}}}{\sqrt{i_v\left(\frac{s+l}{k}\right)}}\right)+1\Bigg\}\sqrt{i_v\Big)\frac{s+l}{k}+x'_1\Big)}} \qquad (J_{E1})$$

$\overline{Ee}$, determined by equation (L_{E1}), is that of an , $\overline{mnDCm}$ or E_1, having the same relative diver- end bases $\overline{CED}$ and $\overline{men}$, corresponding to $\overline{DEC}$ ver $\overline{MNGFM}$ or E has between its end bases ere

$$\frac{\overline{FHG}}{\overline{DEC}}=k=\frac{0.06775}{0.01583}=4.2798$$

neral relation between the ordinates, $y'_{E1}=R'_{E1}$ r'_1, of the generating curve of the tubular enve- $_1$, becomes determined by the equations:

$$\ldots_{E1}x'_1=\sqrt{\frac{\frac{r'^2 n}{k^2}\left(\frac{\sqrt{i_v s+l}}{\sqrt{i_v(s+l)}}\right)\sqrt{i_v\left(\frac{s+l}{k}+x'_1\right)}}{\sqrt{\frac{i_v s+l}{k}+x'_1}+(1-n)\sqrt{i_v\left(\frac{s+l}{k}+x'_1\right)}}} \qquad (M_{E1})$$

the denominator:

$$\ldots\frac{\ldots+l}{\ldots}+x'_1+(1-n)\sqrt{i_v\left(\frac{s+l}{k}+x'_1\right)}$$

of the above fraction becomes equal to 0, which happens w

$$x'_1 = \frac{\frac{i_v s+l}{k} - (1-n)^2 \left\{ i_v \left(\frac{s+l}{k}\right) \right\}}{i_v(1-n)^2 - 1}$$

Ten characteristic ordinates y'_{EI} or radii R'_{EI} correspon ten abscissas x'_1 of various lengths have been computed writer; the results arrived at are entered in the subjoined

TABLE E_1.

1	2	3	4
Reference numbers for cross sections and corresponding butt end frusta of tube $\overline{MNDC}$ of type E_1 (See $\overline{mcedn}$ $\overline{DECm}$, on Plate 16).	Argument x'_1. Length of each butt end frustum cut off tube $\overline{mnDCm}$ of type E_1.	Radius $y'_{EI} = R'_{EI} = \frac{r'}{k} + m x'_1$ of cross section of tube $\overline{mnDCm}$ of type E_1 at distance x'_1 from $\overline{mn}$, viz., radius of small base of butt end frustum cut off tube.	n'_{EI} Throat velocity coefficie $\left[\frac{\text{coeff}}{\text{eff dec ajutage}}\right]_{\text{abdDCca of type } E_1} = \frac{\left[\frac{\text{veloc}}{\text{eff dec ajutage}}\right]_{\text{abdDCc of type}}}{\sqrt{g2h}\left(\left[\frac{\text{coeff}}{\text{eff dec inlet}}\right]_{\text{abdDCca}}\right.}$ for each butt end frustum o $\overline{mnDCm}$ of type E_1.
SECTION	FEET	FEET	
−1	0.002 727	∞	2.3867
+0 at $\overline{men}$	0.000 000	0 029541	2.3867
1	0.001 000	0.026522	2.3867
2	0.003 000	0.023401	2.3867
3	0 005 000	0.021543	2.3867
4	0.007 000	0.020548	2.3867
5	0.010 000	0.019434	2 3867
6	0 030 000	0.017176	2.3867
7	0.050 000	0.016586	2.3867
8	0.100 000	0.016090	2.3867
+9 at $\overline{CED}$	0.192 022	0.015830	2.3867

The outline of the longitudinal section of the envelopin $\overline{mnDCm}$ marked E_1 on Plate 16, is the locus of the extremi

butt ends of imaginary divergent receivers such as
$\overline{cd.142,.142'c}$, $\overline{cd.192,.192'c}$.....any one of which
f increasing uniformly 2.3867 times the proportional
resented by $\sqrt{i_v\left(\frac{s+l}{k}+x'_1\right)}$ corresponding to the
p-stream excursions of molecules in a small freely
ein such as abdca projected through a simple orifice
= 0.009276 ft. in diameter, instead of $\overline{AOB}$=0.0396 ft.,
generally the same proportions as vein $\overline{ABDCA}$, but
it in the ratio of 1 to $\frac{1}{(k=4.2798)}$, viz., when the said
sed in connection with a convergent inlet which has
delivering or supplying efficiency at the small base
the full discharge that can pass continuously through

divergent receiver the capillary attraction of its sides
whole, to increase the efficiency of the tube as a trans-
n momentum, by clearing the way for, and disengaging,
particles from one another, and thus producing
ng increase in the value of i_v, the forced interference
olecules with each other's movements in making their
convergent conoidal tube like E_1, when it is used by
to say, without being accompanied by a divergent re-
on the contrary, invariably cause a decrease in the
d perceptibly diminish the velocity of the stream flow-
he said tube, in addition to which some extra loss of
o doubt, also caused by the increased friction deve-
the sides of the tube.

stated, in such case the supply drawn from the re-
pe section R_1 has to pass the section $\overline{mn}$ with a
to:

$$\left(\frac{\overline{CE^2}}{\overline{me^2}}\right)^n = \sqrt{2g(P_1-P_2)}\left(\frac{.0002505890}{.0008726358} = .287163\right)^{2.3867}$$

$$= \sqrt{2g(P_1-P_2)} \times 0.685352$$

the draught induced through the convergent-divergent
mplete Venturi meter, may be fully satisfied. Now,
t little in excess of the theoretical value of the co-
ux of water from a large reservoir through an orifice in
under a moderate pressure, —a fact which goes to
also the small difference between 2.3867 the actual

value of n and 2.5652 its maximum theoretical value above
lished (see page 288), that the convergent velocity
rator, $\overline{mnCDm}$, has very nearly the proper degree o
vergence or shape, to supply by an unbroken stream
inserted directly in the flat vertical end or side
reservoir R_1, all the water that can flow continuously throu
conduit, $\overline{mnDGFCm}$, under an effective pressure, $(P_1 - P_2)$,
ponding to the mean value of 0.40 adopted for i_v, viz., while t
pressure P_1 on the up-stream side, is finally lowered to P_2
down stream end of this pipe, after having descended as

$$\left\{P_1 - (P_1 - P_2)\left(\frac{veloc_{CED}}{\sqrt{2g(P_1 - P_2)}}\right)^2\right\}$$

in the throat, or section o
mum construction, $\overline{DEC}$; leaving here the atmospheric press
of consideration, as also the loss of velocity and momentum
arily caused by forced mutual interferences of the liquid p
with their rapid gyratory or oscillatory movements and by
creased friction developed in such tubes as E_1, as compared t
gent and cylindrical tubes.

It is, therefore, probable that in order that the greatest e
may be secured in the velocity generator, it should b
somewhat wider at the entrance $\overline{mn}$, or with sides having a
convergence than those of the inlet $\overline{mnCDm}$, viz., so as to r
capable of supplying all the water needed to satisfy the dra
duced by a divergent receiver that would be capable of increa
throat velocity to, say, 3 or 4 times the theoretical velocity
the difference of pressure $(P_1 - P_2)$ instead of only 2.3867 t

The resistance due to friction could, no doubt, also be dim
in some measure by replacing the convergent elongated
nozzle-shaped inlet, $\overline{mnCDm}$, or E_1 by an inlet or mouth piece
the same bases men and $\overline{CED}$ as E_1, and hence the same to
vergence of the sides, but wherein fluid motion would be pro
in the direction $\overline{eOX}$ according to laws differing from thos
govern the flow through E_1.

IV. Typical Convergent Inlets.

Thus far, both tubes, E and E_1, have been viewed in the
conoidal convergent envelopes of series of divergent tubes
$\overline{CD11'C}$, $\overline{CD22'C}$, $\overline{CD44'C}$.....$\overline{CDGFC}$, in the case of rece
or $\overline{cd.182.182'c}$, $\overline{cd.142,.142'}$, $\overline{cd.092.092'c}$....$\overline{cdDCc}$, in the case

ı tubes, when kept running full, are capable of induc-
y, each tube by itself, a velocity in the small base
2.3867 times as large as the theoretical velocity due
e of the pressures P_1 and P_2, which obtain respective-
d down stream ends of a complete convergent-diver-
ıch as $\overline{MNDGFCM}$ or $\overline{mnDGFCm}$, for which reason
cluded, a explained in Cap. III (pages 291-2), that the
eloping tube E_1 is capable of supplying all the liquid
rgent tube CDGFC applied to the small or tip end
able of drawing through it from the reservoir R_1, to
led. But when acting independently, viz., unaccom-
vergent draught tube, such as $\overline{CDGFC}$, the said tube
erforms only the same duty as regards discharging
ther conical or conoidal convergent inlet or velocity
ng sides with a total convergence represented by

e:n $\sqrt{i_v\left(\frac{s+l'}{k}\right)+l'}$, the total proportional velocity of

n, which corresponds to the periods of up-stream ex-
ecules in the freely contracted vein $\overline{abdca}$, constitut-
iiar to $\overline{ABDCA}$, to the series of enveloped divergent
en cmndc and $\overline{cCDdc}$, and which extends a distance
down stream side of the entrance $\overline{mn}$,—is continual-

ıced from $\sqrt{i_v\left(\frac{s+l}{k}\right)+l'_1}$ to the submultiple of

, and the proportional velocity of vein propagation

generated during the periods of down stream mole-
s is at the same time increased, so as to become
ctually) equal to:

$$\overline{}'_1 + \left\{\sqrt{i_v\left(\frac{s+'}{k}+l'_1\right)} - \frac{1}{n}\sqrt{i_v\left(\frac{s+'}{k}+l'_1\right)}\right\}$$

tube E_1, when used by itself as a convergent velocity
h we may designate by E_{1C} instead of the velocity
f the liquid which obtains in an efficient conoidal
ı subsidiary freely contracted vein such as $\overline{ABDCA}$,
y increased, as a result of the transformation of
mass and velocity factors of the vein-momentum,
munication of motion such as takes place in the
$\overline{CDGFC}$, the velocity of the stream formed in tube

E_{IC} or $\overline{mnDCm}$, may be viewed as being the result of the
tion of the liquid into this tube, through a suitable con
conoidal inlet modelled after a subsidiary freely contracte
$\overline{rqmnr}$, generated in a simple orifice, ro'q, in a thin plate at
tance eo' above the entrance, $\overline{men}$, corresponding in a man
the distance, $\overline{OE}$, between the section $\overline{CED}$ in the free vein, $\overline{A}$
and the orifice $\overline{AOB}$,—and the absolute number of liquid-mo
than can pass under a given pressure in the unit of time t
the orifice in a thin plate, $\overline{ro'q}$, may be considered to be con
ly diminished as the stream advances in tube E_{IC}, so as
equal, at any point of the trajectory, $\overline{eE}$, below $\overline{mn}$, to the q
of liquid carried by a similar free vein, but which is s
approximately, in the ratio of the cross section of the con
vein generated in the orifice, $\overline{ro'q}$, to the cross section of t
vergent tube. $\overline{mnDCm}$, at the said point.

As already observed in Chapter II. of this paper (see pag
it will readily be seen that, while in a divergent receiver
volving or oscillating liquid particles can easily be deflec
lateral communication of motion, so that the resultants
ethereal forces acting in the direction of the flow which are
inward or towards the axis in a freely contracted liquid vei
be turned outwards or away from the axis of the vein, and a
formation of the vein-momentum with increased discharge ca
be induced, in the case of an incompressible fluid flowing t
a convergent tube, the said particles cannot be artificially de
from their normal paths so that the resultants of the mo
forces may be turned inwards and the molecules pressed
together and impelled forward with greater rapidity, than th
naturally pressed together or impelled in the freely contracte
without the assistance of an extraneous force. such as that
would result from a chemical or a physical change in the co
tion of the fluid taking place at the time. Therefore, in the a
of such a force, a portion of the moving molecules must be r
towards the source of supply, with the result that a corresp
reduction in the motion of translation of the vein takes pl
the convergent tube E_{IC} in lieu of an increased quantity of
being drawn through the tube, as in the case of the trans
tion of vein momentum which is effected in a divergent re
the momentum here lost or abstracted by resolving itself aga
molecular motions, or pressure; varying slightly in quanti
intensity with the type of convergent inlet used, viz., in the
manner as when pressure is stemmed in a contrary direct
the butt end of a corresponding divergent tube.

ns, as there was no method known to the writer
tly the magnitude of the vein-momentum re-
e, or other molecular movements, he found it
purpose of expressing in terms of the linear
, l'_1, which determine the fundamental propor-
gent tube $\overline{mnDCm}$ of type E_{1C}, the fraction,
st stated, the total proportional velocity of vein
onding to the periods of up-stream excursions
freely contracted vein, is continually being
ams passing through tubes such as E_{1C} —to
from this tube as being equivalent, or equal, to
divergent receiver, $\overline{cdDCc}$, which has the same
s $\overline{CDGFC}$, as regards actual transformation of

eived, when keeping in view the explanations
o the theoretical virtual transformation of vein-
ver E with convergent sides, at page 290, that
, which has hereinafter been replaced by the
e very nearly equal to the fraction or submul-
of the volume of liquid carried in the unit of

contracted vein projected through the simple
by a stream discharged through the contacted
hich the tube E_{1C} permits to pass through its
the same time.

l also point out here: that in view of the fact
page 295, that in a convergent-divergent ajutage
ons of the McGill Venturi meter as fixed and
poses of this paper, the velocity co-efficient

2) determined for its entrance $\overline{mn}$, turns out

ual to that of a vein projected freely under the
rough an orifice in a thin plate of the same dia-
arent that, while in the case of the divergent
e assumed auxiliary contracted vein, $\overline{ABDCA}$,
bly above the small base, $\overline{CED}$, of the said
ontrary in the conjugate convergent inlet,
onding free vein, $\overline{rqmnr}$, necessarily lies prac-
e tube of type E_{1C}, so that the plane of the
which this free vein is formed, coincides very
rance, $\overline{men}$, of the inlet, as it should do, as a

rule, in all ajutages composed of conjugate convergent and
gent tubes, except in cases where the sides of the
tube converge less, on the whole, than those of the conoid as
by the freely contracted vein projected through a simple orifice
to its entrance $\overline{mn}$, in the length $\overline{eE}$ or l'_1 of the said tube.

By following now the same train of reasoning as that whi
up to equations B_G, B_B, B_C,—and G_G, G_B, G_C, G_E in the cases
typical divergent tubes, A, B, C and E, (See Chap. II. and III
reach, therefore, the conclusion that as a result of the addit
the convergent tube, $\overline{mnDCm}$, to the orifice $\overline{mn}$, in the bott
the end of the reservoir, R_1, the following relation must
viz.:

$$\left[\begin{array}{c}\text{coeff veloc}\\ \text{infl entr } \overline{mn}\\ \text{conv tube } E_{IC}\\ \text{of length } x'_1\end{array}\right] = \left[\begin{array}{c}\text{coeff veloc}\\ \text{entr } \overline{men}\\ \text{ajutage}\\ \overline{mnDGFCm}\\ \text{or of}\\ \text{orifice } \overline{mn}\end{array}\right] \times \frac{n'_{EIC}\sqrt{i_v\left(\frac{s+l}{k}+x'_1\right)}}{\sqrt{i_v\left(\frac{s+l}{k}+x'_1\right)}}$$

(

and replacing x'_1, by l'_1, we get:

$$\left[\begin{array}{c}\text{coeff veloc}\\ \text{infl entr } \overline{mn}\\ \text{conv tube } E_{IC}\\ \text{of length } l'_I\end{array}\right] = \left[\begin{array}{c}\text{coeff veloc}\\ \text{entr } \overline{men}\\ \text{ajutage}\\ \overline{mnDGFCm}\\ \text{or of}\\ \text{orifice } \overline{mn}\end{array}\right] \times \frac{n_{EIC}\sqrt{i_v\left(\frac{s+l}{k}+l'_1\right)}}{\sqrt{i_v\left(\frac{s+l}{k}+l'_1\right)}}$$

(G

We must also have:

$$\left[\begin{array}{c}\text{coeff veloc effl}\\ \text{conv tube } E_{IC}\\ \text{of length } l'_1\\ \text{at distance } x'\\ \text{from entrance}\end{array}\right] = \frac{\left(r'^2_C = \overline{me}^2\right)}{R'^2_{EI} = y'^2_{EI}} \left[\begin{array}{c}\text{coeff veloc}\\ \text{entr } \overline{men}\\ \text{ajutage}\\ \overline{mnDGFCM}\\ \text{or of}\\ \text{orifice } \overline{mn}\end{array}\right] \times \frac{n_{EIC}\sqrt{i_v\left(\frac{s+l}{k}+\right.}}{\sqrt{i_v\left(\frac{s+l}{k}+\right.}}$$

(G

where the value of n_{EIC} is, according to equation (J_{EI}) (see pag
determined by the following formula; l'_1, being substituted
in the said equation, viz.:

$$\frac{\sqrt{\frac{i_v s+l}{k}+l'_1} - \sqrt{i_v\left(\frac{s+l}{k}+l'_1\right)}}{\left\{\frac{r'^2_c}{(r'_c-m_c l')^2}\left(\frac{\sqrt{i_v s+l}}{\sqrt{i_v(s+l)}}\right)+1\right\}\sqrt{i_v\left(\frac{s-l}{k}+l'_1\right)}} \qquad (J_{EIC})$$

ie total length $\overline{Ee} = \overset{ft.}{0.192022}$ of the convergent tube

dius $\overline{em} = \overset{ft.}{0.029541}$, m' the tangent $\frac{\overline{em}-\overline{CE}}{\overline{Ee}} = 0.0714$

le of convergence of the sides of tube E_{IC}, $i_v = 0.40$

166, $k = \frac{\overline{FGH}}{\overline{CED}} = \frac{0.06775}{0.01583} = 4.2798$ and

ng a co-efficient varying between 0.50 for simple

ery great pressures and 0.69 for simple orifices under sures, in all cases where the inlets have sides con- whole, more than those of the corresponding freely s, and increasing for inlets with sides converging of the said free veins, up to about 0.83 for inlets ides, viz., cylindrical tubes.

Equation (J_{EIC}) gives $n_{EIC} = 0.427762$,

while: $\frac{1}{n_{EI}} = \frac{1}{2.3867} = 0.418988$

t of the discrepancy between these two results is pro- y an unavoidable want of perfect accuracy in the given to i, s, l and k.

re (G_{EIC}) with (G_G) (page 271), we see that we can

$$\sqrt{i_v\left(\frac{s+l}{k}+x'_1\right)} = \sqrt{i_v\left(\frac{s+l}{k}+j_{EIC}\,x'_1\right)}$$

vs that we can also put very nearly:

$$_{EIC} = \frac{n'^2_{EIC}\left(\frac{s+l}{k}+x'_1\right)-\left(\frac{s+l}{k}\right)}{x'_1} \qquad (F_{EIC})$$

With the aid of formula (G'_{EIC}) and placing the co-eff velocity of efflux from the orifice in a thin plate correspo the entrance $\overline{mn}$ uniformly at a mean value of 0.64 in 0.685352, the fraction deduced from purely theoretical co tions, the writer computed the velocity co-efficients, etc., er Table E_{IC}, for cross sectons $\overline{(.191, .191')}$, $\overline{(.189, .189')}$, $\overline{(.18}$ $\overline{(.180, .185')}$, $\overline{(.182, 182')}$, $\overline{(.162, .162')}$, $\overline{(.142, .142')}$, $\overline{(.092, .09}$ corresponding to ten frusta of the convergent inlet mnDCm E_{IC}, which are numbered 0 to 9.

TABLE E_{IC}.

1	2	3	4	5
Designation of butt end frusta—of convergent tube $\overline{mnDCm}$ of type E_{IC}, x'_1 feet long from entrance $\overline{mn}$ towards outlet $\overline{CD}$.		Argument x'_1 Length of butt end frustum of convergent tube $\overline{mnDCm}$ of type E_{IC} measured from entrance $\overline{mn}$ towards outlet $\overline{CD}$.	Radius R'_{EIC} of cross section of convergent tube $\overline{mnDCm}$ of type E_{IC} at distance x'_1 from its entrance $\overline{mn}$—Computed by formula (M_{E1}).	Velocity co-efficient in cross section of convergent tube $\overline{mnDCm}$ of type E_{IC}, and length l_1 taken at distance x'_1 from entrance mn, according to formula (G''_{EIC}).
By numbers corresponding to those in Table E.	By letters and figures marked on Plate 16.			
SECTION		FEET	FEET	
−1		0.002 727	∞	0.000 000
0 at $\overline{mn}$	$\overline{mn}$ n m,m	0.000 000	0.029 541	0.363 768
+1	$\overline{mn.191.191}$m	0.001 000	0.026 522	0.339 642
2	$\overline{mn.191.189}$m	0.003 000	0.023 401	0.436 111
3	$\overline{mn.187.187}$m	0.005 000	0.021 543	0.514 768
4	$\overline{mn.185.185}$m	0.007 000	0.020 548	0.565 840
5	$\overline{mn.182.182}$m	0.010 000	0.019 434	0.632 570
6	$\overline{mn.162.162}$m	0.030 000	0.017 176	0.809 731
7	$\overline{mn.142.142}$m	0.050 000	0.016 586	0.868 460
8	$\overline{mn.092.092}$m	0.100 000	0.016 090	0.922 823
+9 at $\overline{CED}$	$\overline{mn}$ D $\overline{Cm}$	0.192 022	0.015 830	0.953 390

furthermore determined the shapes of convergent ors or inlets, A_C, B_C, C_C, B_C, corresponding respec- ergent receivers, $\overline{CDGFC}$, of types A, B, C, D, as re- ransformation of vein-momentum and supplying puted in each case velocity co-efficients correspond- en above for the convergent tube E_{1C}.

d that by the addition of a convergent tube, $\overline{mnDCm}$, rifice, $\overline{mn}$, in the side of reservoir R_1, the total pro- ty of vein formation, generated during the periods of sions of molecules is reduced to $\sqrt{i_v s_c + i_v j_{AC} x'}$; and sponding velocity generated during the periods of cursions of molecules is simultaneously increased to: $\sqrt{i_v(s_c + j_{AC} x)} - \sqrt{i_v(s_c + x')}$, where s_c corresponds to s projected through the orifice, $\overline{AOB}$, and is equal to

for the free vein projected through the orifice aob

tor less than unity.

nation of vein momentum is the reverse of that effect- ent receiver $\overline{CDGFC}$, of Type A. We have here to sub- ion (F_G) (see page 271); $\frac{r}{k}$ for r, $\frac{s}{k}$ for s, $\frac{l}{k}$ for l, Equation (F_G) is thus transformed into:

$$\frac{\left\{\sqrt{i_v\left(\frac{s+i}{k}\right)x'} + \sqrt{i_v\left(\frac{s+i}{k}\right)}\left(\frac{r'_c 2}{(r'_c - m_c x'_c)2}\right)\right\}^2}{\left\{\frac{i_v s+l}{k} + x'_c + \sqrt{i_v\left(\frac{s+l}{k} + x'_c\right)}\right\}^2\left(\frac{s+l}{k}\right)} - \frac{s+l}{k\,x'_c} \qquad (F_{AC})$$

e replace x'_c by l'_1, the length $\overline{Ee}$ of the tube $\overline{cdDCc}$, nds, in general, to $EH = l'$ in divergent receiver E, solution of the resulting equation gives us 0.139157 g, however, to the unavoidable want of perfect ac- elative values given to r, s, i, l and k—the values of for the butt end frusta of Tube A_C decrease slightly ths x'_c—instead of remaining uniformly 0.139157, as ubjoined table A_C.

Again, substituting x'_c for x', $\frac{l}{k}$ for l and r'_c for r', equatio
(See page 272) becomes:

$$y'_{AC} = R'_{AC} = r'_c - m'_c x'_c =$$

$$\frac{r'_c}{\sqrt{\sqrt{\frac{\left\{\sqrt{\frac{i_v s+l}{k}} + x'_c + \sqrt{i_v\left(\frac{s+l}{k} + x'_c\right)}\right\}^2 \left\{\frac{s+l}{k}\right\}}{\left(\frac{s+l}{k} + j_{AC}x'_c\right)\left(\frac{i_v s+l}{k}\right)}} - \frac{\sqrt{i_v}}{\sqrt{i_v}}}}$$

(I_A

Treating now inlet $\overline{mnDCm}$ of type A_C as a conve
tube applied directly to a simple orifice $\overline{mn}$, we can, by reasoni
explained in the case of equation (G_G), determine very nearl
velocity co-efficient for the entrance $\overline{mn}$ to the convergent tub
of length l'_1 by means of function (G_{AC}), viz.:

$$\left[\begin{array}{c}\text{coeff veloc}\\ \text{in entr } \overline{mn}\\ \text{conv tube Ac}\\ \text{of length } l'_1\end{array}\right] = \frac{\left[\begin{array}{c}\text{coeff veloc}\\ \text{eff orifice}\\ \overline{mn} = 0.64\end{array}\right]\sqrt{i_v\left(\frac{s+l}{k} + j_{AC}l'_1\right)}}{\sqrt{i_v\left(\frac{s+l}{k} + l'_T\right)}}$$

(

Finally, replacing x'_c by l'_1 in equation (G_{AC}) and multi
its second member by $\frac{r'^2_c = \overline{me}^2}{R'^2_{AC} = y'^2_{AC}}$, we obtain for determining, v
narrow limits, the co-efficient of velocity in any cross sectio
distance x'_c from the entrance $\overline{mn}$ of the convergent
tube Ac of length l'_1, the expression:

$$\left[\begin{array}{c}\text{coeff veloc}\\ \text{in cross}\\ \text{section at}\\ \text{distance } x'_c\\ \text{from entr } \overline{mn}\\ \text{conv tube Ac}\\ \text{of length } l'_1\end{array}\right] = \frac{(r'^2_c = \overline{me}^2)}{(R'^2_{AC} = y'^2_{AC})}\left\{\frac{\left[\begin{array}{c}\text{coeff veloc}\\ \text{eff orifice}\\ \overline{mn} = 0.64\end{array}\right]\sqrt{i_v\left(\frac{s+l}{k} + j_{AC}\right.}}{\sqrt{i_v\left(\frac{s+l}{k} + l'_1\right)}}\right.$$

(G'_A

known quantities i_v, s, l and k by their respec-
es, viz.: i_v by 0.40, s by 0.0125 ft., l by 0.03166
, the numerical solutions of equations (F_{AC}),
G'_{AC}) for a few characteristic values of the
the results which are entered in the subjoined

TABLE A_C.

2	3	4	5
gument istance h cross ion of ergent tube Cm, e A_C, n en- e mn	Radius $R'_{AC} = y'_{AC} = (r'_c - m'_c x_c)$ of each cross section of convergent inlet mnDCm, type A_C, at distance x'_c from its entrance mn. Computed by formula (I_{AC}).	Velocity coefficient for cross section of convergent inlet mnDCm, type A_C, l'_1, feet long, taken at distance x'_c from entrance mn, according to formula (G'_{AC}).	j_{AC} Proportional uniformly reduced intensity of ethereal force corresponding to $i_v f$, which is induced in each butt end frustum of the convergent tube mnDCm type A_C. (See foot note)
EET	FEET		
3 025	∞	0.000 000	
2 000	0.047 107	0.107 752	0.139 157
0 000	0.029 541	0.273 996	0.139 157
1 000	0.028 343	0.297 648	0.139 157
3 000	0.026 765	0.333 788	0.139 157
6 000	0.024 970	0.383 494	0.139 157
0 000	0.023 337	0.455 122	0.139 157
0 000	0.020 981	0.543 181	0.139 157
0 000	0.018 241	0.718 618	0.139 157
0 000	0.016 751	0.852 144	0.139 157
2 022	0.015 835	0.953 585	0.139 157

$_c$, computed by means of formula (F_{AC}), increase slightly with the
end frusta of tube A_C, owing to unavoidable inaccuracies in the
r, s, l, i, and k. Thus: for $x'_c = +0.001$, j_{AC} is found to be 0.03872,
32 and for $x'_c = 0.192022$, $j_{AC} = 0.139157$.

The value of x'_c for which R'_{AC} becomes ∞ has be
lished by putting the denominator

$$\sqrt{\sqrt{\frac{\left\{\sqrt{\frac{i_v c+l}{k}+x'_c}+\sqrt{i_v\left(\frac{+l}{k}+x'_c\right)}\right\}\left(\frac{s+l}{k}\right)}{\left(\frac{s+l}{k}+j_{AC}x_c\right)\left(\frac{i_v c+l}{k}\right)}} - \sqrt{}}$$

equal to zero, whence we deduce the value of x'_c in tern
l, k and j_{AC} to be as per equation:

$$x'_c = +\sqrt{\frac{4i_v\left(\frac{(i_v s+l)\,(s+l)}{k^2}\right)+\left(\frac{i_v c+l}{k}\right)^2}{(1+i_v-j_{AC})^2-4i_v}} +$$

$$\sqrt{\left\{\frac{\left(\frac{i_v c+l}{k}\right)\left(1-i_v-j_{AC}\right)-\frac{2i_v((s+l)+(i_v s+l))}{k}}{(1+i_v-j_{AC})^2-4i_v}\right\}^2 -}$$

$$\left\{\frac{\left(\frac{i_v c+l}{k}\right)\left(1+i_v-j_{AC}\right)-\frac{2i_v((s+.)+(i_v s}{k}}{(1+i_v-j_{AC})^2-4i_v}\right.$$

2o. The writer assumed the efflux through the sect
viewed as an orifice in a thin plate in the side of a reserv
modified by the addition of a convergent tube, $\overline{mnDCm}$, to

of such a shape that the total proportional velocity on generated during the periods of up-stream excur-ıles, becomes reduced to $\sqrt{i_v(s_c + x'_c)} - q_c x'_c$, and the elocity generated during the periods of down-stream eased to $\sqrt{i_v(s_c + x'_c)} + q_c x'_c$, where s_c again corresponds vein projected through the orifice, $\overline{AOB}$; the trans-ein momentum here effected in convergent inlet, B_C, rse of that brought about in divergent receiver B. ngent m'_c negative the same as in the case of the t tube A_C, on account of the sides of both tubes, A_C ging towards each other respectively, and substituting $= \overline{EH}$, equation (F_B) (see page 279), is thus trans-

$$\frac{\overline{\frac{s+l}{k}} + l'_1 - \frac{r'^2_c}{(r'_c - m'_c l'_1)^2}\left(\frac{\sqrt{i_v s + l}}{\sqrt{i_v(s+l)}}\right)\sqrt{i_v\left(\frac{s+l}{k} + l_1\right)}}{l'_1\left\{\frac{r'^2_c}{(r'_c - m'_c l'_1)^2}\left(\frac{\sqrt{i_v s + l}}{\sqrt{i_v(s+l)}}\right) + 1\right\}} \qquad (F_{BC})$$

$_B$) becomes:

$$_c - m'_c x'_c = r'_c \sqrt{\frac{\left(\frac{\sqrt{i_v(s+l)}}{\sqrt{i_v s + l}}\right)\sqrt{i_v\left(\frac{s+l}{k} + x'_c\right)} + q_c x'_c}{\sqrt{\frac{i_v s + l}{k} + x'_c} - q_c x'_c}} \qquad (I_{BC})$$

on (G_B), (page 279), we deduce for the determination coefficient in the entrance $\overline{mn}$ to the convergent tube of length l'_1, the expression:

$$\left.\begin{matrix}\text{eloc}\\ \text{rance}\\ \text{, tube}\\ \text{gth } l'_1\end{matrix}\right] = \frac{\left[\begin{matrix}\text{coeff veloc}\\ \text{eff orifice}\\ \overline{mn} = 0{,}64\end{matrix}\right]\left(\sqrt{i_v\left(\frac{s+l}{k} + l'_1\right)} + q_c l'_1\right)}{\sqrt{i_v\left(\frac{s+l}{k} + l'_1\right)}} \qquad (G_{BC})$$

and for arriving at the velocity co-efficient in any cross se
the convergent tube B_C. l'_1 feet long, taken at the distance
low its entrance $\overline{mn}$, we have the expression :

$$\begin{bmatrix}\text{coeff veloc}\\ \text{eff cross sect.}\\ \text{conv. tube Bc}\\ \text{at distance } l'_1\\ \text{from entr } \overline{mn}\end{bmatrix} = \frac{(\nu'_c{}^2 = \overline{me}^2)}{R'^2_{BC} = \nu''^2_{BC}} \cdot \left(\frac{\begin{bmatrix}\text{ceoff veloc}\\ \text{eff orifice}\\ \overline{mn} = 0.64\end{bmatrix} \sqrt{i_v\left(\frac{s+l}{k}+l'_1\right)} +}{\sqrt{i_v\left(\frac{s+l}{k}+l'_1\right)}} \right.$$

Also: comparing (G_{BC}) with (G_{AC}), (page 304), and putti

$$\sqrt{i_v\left(\frac{s+}{k} + x'_c\right)} + q_c x'_c = \sqrt{i_v\left(\frac{+l}{k} + j_{BC}\, x'_c\right)}$$

we obtain, the same as in the case of j_B in the divergent
B, the following equation, (F_{BC}), for determining within
limits in terms of i, s, l, k, x_c and g. the relative intensity
the ethereal force corresponding to the force $i_v f$ which obt
the small base of the convergent tube of type B_C, after t
has traversed a distance x'_c from the entrance $\overline{men}$, viz.:

$$j_{BC} = \frac{\left\{\sqrt{i_v\left(\frac{s+l}{k} + x'_c\right)} + q_c x'_c\right\}^2 - i_v\left(\frac{s+l}{k}\right)}{i_v\, x'_c}$$

Substituting for the symbols in equation (F_{BC}), their nu
values as above established, we find that q_c is equal to - 0.8480
the results of the numerical solutions of equations (I_{BC}), $(F$
(G_{BC}) for fifteen characteristic values of the argument x'_c are
in

TABLE B_C.

2	3	4	5
rgument x'_c Distance of ach cross ection of onvergent ube $\overline{mnDCm}$, ype B_C, from $\overline{\text{ntrance mn}}$.	Radius $R'_{BC} = y'_c = (r'_c - m'_c x'_c)$ of cross section of tube of type B_C, at distance x'_c from entrance $\overline{mn}$, computed by means of formula (I_{BC}).	Coefficient of velocity in cross section of convergent tube of type B_C, l'_1, feet long, at distance x'_c from entrance $\overline{mn}$, as per formula (G'_{BC}).	Proportional intensity j_{BC} of the ethereal force corresponding to $i_v f$, which is induced in convergent tube $\overline{mnDCm}$ of type B_C, after the vein has traversed a distance x'_c from base $\overline{\text{men}}$, according to formula (F'_{BC}).
FEET	FEET		
0.008 600	∞	0.000 000	0.873390
0.008 000	0.052 462	0.086 779	0.556470
0.006 000	0.035 872	0.185 609	0.813026
0.004 000	0.032 613	0.224 568	0.779672
0.002 000	0.030 674	0.253 577	0.751941
0.000 000	0.029 541	0.273 692	0.736297
0.001 000	0.029 098	0.282 089	0.726421
0.003 000	0.028 362	0.296 920	0.697290
0.006 000	0.027 509	0.315 618	0.668753
0.010 000	0.026 640	0.336 545	0.636081
0.020 000	0.025 092	0.379 351	0.569030
0.050 000	0.022 342	0.478 484	0.431794
0.100 000	0.019 494	0.628 507	0.289175
0.150 000	0.017 367	0.791 885	0.195950
0.192 022	0.015 830	0.953 125	0.133895

ter undertook to determine the nature and extent of
ion of vein-momentum, as indicated by the varia-
ocity co-efficients and in the relative intensities of
ce corresponding to $i_v f$, which is effected in a liquid

vein formed in a conoidal convergent inlet $C_{C'}$ determined
revolution of a zone $\overline{mnDCm}$ of a kind of cubical hyperbol
an asymptote, $\overline{Ek}$, coinciding with the axis, $\overline{OX}$, of the vein;
ing that when referred to rectangular axes of co-ordinates
the hyperbolic curve which generates by revolving around t
$\overline{peE}$, the conoidal frustum constituting the convergent tube
of type $C_{C'}$, is determined by the equation:

$$y'^2_c = R'^2_c = (r'_c - m'x'_c)^2 = \frac{r'^2_c\, p_c}{(p_c + x'_c)\, c'}$$

p_c denoting a constant distance $\overline{ek}$, c', a constant arbitrary
ient, r'_c the radius em and m', in general, the tangent of th
of convergence corresponding to abscissa, x'_c, which is e
$\frac{(r'_c - y'_c)}{x'_c}$. Putting in equation ($K_{CC}$):

$$x'_c = (l'_1 = \overline{eE}) \text{ and } m' = m'_c = \frac{\overline{em} + \overline{EC}}{\overline{eE}},$$

we get:

$$(r'_c - m'_c\, l'_1) = \frac{r'^2_c\, p_c}{(p_c + l'_1)\, c'},$$

whence

$$p_c = \frac{l'_1\,(r_c - m'_c\, l'_1)^2 c'}{(r'_c - m'_c\, l'_1)^2 c' - r'^2_c}$$

a formula in which all the letters represent known quantit
being equal to 0.192022 ft., r'_c to 0.029541 ft., and m'_c to
Adopting, as in the case of divergent receiver $\overline{CDGFC}$ of
unity or 1 for co-efficient c', we arrive at:

$$p_c = ek = -0.077351 \text{ ft.}$$

the arbitrary co-efficient c' taken equal to 1, the
e $l = \overline{oE}$ is substituted for the length x of any frus-
l,, of the free vein $\overline{ABDCA}$, the following relations
to equation (I_C) (see page 282), hold good, viz., the
ted by (I_{CC}), where $\overline{kx}$ and $\overline{ky}$ are taken as axes of
stead of $\overline{ex}$ and $\overline{em}$; p_c becoming thus positive.

$$y'_{cc} = R'_{cc} = (r'_c - m'_c x'_c) = \sqrt{\frac{r'^2_c p_c}{p_c + x'_c}}$$

$$\frac{r'_c}{\left\{\frac{s+l}{k} + x'_c + \sqrt{i_v\left(\frac{s+l}{k} + x'_c\right)}\right\}^2 \left\{\frac{s+l}{k}\right\}}{\left(\frac{s+l}{k} + j_{cc}x'_c\right)\left(\frac{i_v s+l}{k}\right)} - \frac{\sqrt{i_v(s+l)}}{\sqrt{i_v s+l}}\Bigg\}^{\frac{1}{2}} \qquad (I_{cc})$$

squaring, reducing, etc., in the two last members of
e successively at equations :

$$\frac{p_c}{p_c + x'_c} = \frac{\left(\sqrt{\frac{i_v s+l}{k}}\right)\left(\sqrt{\frac{s+l}{k} + j_{cc}x'_c}\right)}{\sqrt{i_v\left(\frac{s+l}{k} + x'_c\right)}\Big\}^2 \left\{\frac{s+l}{k}\right\} - \left(\sqrt{\frac{s+l}{k} + j_{cc}x'_c}\right)\left(\sqrt{\frac{i_v s+l}{k}}\right)} \qquad (I_{cc})$$

$$\frac{l}{} + j_{cc}x'_c\left\{\sqrt{\frac{i_v s+l}{k}} + \sqrt{i_v\left(\frac{s+l}{k}\right)}\right\}\left\{\frac{p_c}{p_c + x'_c}\right\}$$

$$\sqrt{\left\{\sqrt{\frac{i_v s+l}{k}} + x'_c + \sqrt{i_v\left(\frac{s+l}{k} + x'_c\right)}\right\}^2 \left\{\frac{s+l}{k}\right\}} \qquad (I''_{cc})$$

uce, in general, for the value of j_{cc} in a convergent
f type C_C having the same contraction in a given dis-
tube of type A_C .

$$j_{cc} = \frac{\left(\frac{p_c}{p_c+x'_c}\right)^2 \left\{\sqrt{\frac{i_v s+l}{k}+x'_c}+\sqrt{i_v\left(\frac{s+l}{k}+x'_c\right)}\right\}^2 \left(\frac{s+l}{k}\right)}{x'_c\left\{\sqrt{\frac{i_v s+l}{k}}+\sqrt{i_v\left(\frac{s+l}{k}\right)}\left(\frac{p_c}{p_c+x_c'}\right)\right\}^2} -$$

We have, moreover, the same as for convergent inlet tube $\overline{m}$
of type A_{CC} for ascertaining very nearly the value of the veloci
efficient in entrance $\overline{mn}$ of a convergent tube C_{CC} of length l'_1,
tion :

$$\begin{bmatrix}\text{coeff veloc}\\ \text{infl entrance}\\ \overline{mn}\text{ conv.}\\ \text{tube Cc. of}\\ \text{length } l'_1\end{bmatrix} = \frac{\begin{bmatrix}\text{coeff veloc}\\ \text{eff simple}\\ \text{orif. } \overline{mn}.=0.64\end{bmatrix}\sqrt{i_v\left(\frac{s+l}{k}+j_{cc}l'_1\right)}}{\sqrt{i_v\left(\frac{s+l}{k}+l'_1\right)}}$$

(

and

$$\begin{bmatrix}\text{coeff veloc}\\ \text{eff outlet}\\ \text{conv. tube Cc}\\ \text{of length } l',\text{at}\\ \text{distance } \overline{x'c}\\ \text{from ent } \overline{mn}\end{bmatrix} = \frac{y'^2_c=\overline{em}^2}{R'^2_{cc}=y^2_{cc}} \quad \frac{\begin{bmatrix}\text{coeff veloc}\\ \text{eff orif}\\ \overline{mn}=0.64\end{bmatrix}\sqrt{i_v\left(\frac{s+l}{k}+j_{cc}l'\right.}}{\sqrt{i_v\left(\frac{s+l}{k}+l'_1\right)}}$$

(

Giving to the letters in the above formulas their proper num
values, and performing the operations indicated, j_{cc} is found
equal to 0.139215 for $x'_c = l'_1$, and the radii, R_{cc}, of the hyperbo
convergent tube, C_c, entered in the subjoined Table, C_c, are a
at, together with the corresponding velocity co-efficients based
co-efficient of 0.64 for influx through an entrance, $\overline{mn}$, correspo
to a simple orifice.

TABLE C_C.

2	3	4	5
ument istance ss sec- of con- nt in- be DCm, e C_C, its en- e mn.	Radius R'_{CC} $y'_{=cc}=(r'_c - m_c x'_c)$ of cross section of tube mcDCm of type C_C at distance x'_c from entrance mn. Computed according to formula: $R'_{CC}=\frac{\sqrt{r_c^2 p_c}}{p_c + x'_c}$ (I_{CC})	Coefficient of velocity in cross section of convergent tube mnDCm of type C_C, l'_c, feet long, taken at distance x'_c from entrance mn, as per formula (G'_{CC}).	Proportional intensity j_{cc} of ethereal force corresponding to $i_c f$, for each butt end frustum of convergent tube mnDCm of type C_C according to formula (F_{CC})
ET	FEET		
7 351	∽	0.000 000	
0 000	0.095 760	0.026 061	
0 000	0.062 367	0.069 024	
0 000	0.049 381	0.098 003	
0 000	0.037 629	0.168 777	
0 000	0.034 306	0.203 058	
0 000	0.031 609	0.239 187	
8 568	.....	.....	1.165391
0 000	0.029 541	0.273 848	
0 000	0.027 798	0.309 266	0.826672
0 000	0.026 332	0.344 661	0.714816
0 000	0.023 984	0.415 439	0.550183
0 000	0.019 509	0.627 900	0.289876
2 022	0.015 830	0.953 668	0.139215

l of equations (F_{AC}), (I_{AC}), (G_{AC}) and (G'_{AC}), 6), the writer computed the numerical values of the co-efficients of velocity in eight cross sec-

re, unavoidably, only approximate.

tions of the complete conical tube $\overline{mnDCm}$, and at the out
the eight corresponding butt end-frusta of various lengths
the said convergent inlet $\overline{mnD}Cm$, with straight sides. This
which is also designated as inlet D_c has a radius $R'_{DC} =$
0.029541 ft. at the entrance $\overline{mn}$, a radius, $r' = \overline{CE}$, of 0.015830
the outlet CED, and a total length $l'_1 = \overline{eE}$ of 0.192022 ft.; i
taken uniformly at 0.40 and the co-efficient of velocity of
through the simple orifice, $\overline{mn}$, at 0.64, as heretofore.

The results obtained are given in

TABLE D_C.

1	2	3	4	5	
Reference numbers for cross sections and corresponding butt end frusta of conical inlet tube $\overline{mnDCm}$ of type D_C.	Argument x'_c. Distance of each cross section of conical tube $\overline{mnDCm}$, type D_C, from its entrance $\overline{mn}$.	Radius $R'_{DC} = r'_{DC} - (r'_c - m_c x'_c)$ of cross section of tube $\overline{mnDCm}$, type D_C, taken at distance x_c from entrance $\overline{mn}$, computed by formula (I_{AC}).	j_{DC} proportional intensity of the ethereal force corresponding to $i_v f$, in each butt end frustum of conical tube $\overline{mnDCm}$ type D_C, according to formula (F_{AC})	Coefficient of velocity in cross section of complete conical tube $\overline{mnDCm}$, type D_C, l'_1 feet long, taken at a distance x'_c from entrance $\overline{mn}$, as per formula (G'_{AC}).	Co of of e thr smal $\overline{CD}$ end of c ent t m type lengt as g (G'_{AC} placi by x'
SECTION	FEET	FEET			
−1	0.008 568	0.030 153	1.043 783	0.262 500	0.62
0 at men	0.000 000	0.029 541		0.273 482	
+1	0.005 000	0.029 184	1.029 452	0.280 214	0.65
2	0.010 000	0.028 827	0.997 644	0.287 198	0.67
3	0.025 000	0.027 756	0.904 047	0.309 789	0 70
4	0.050 000	0.025 971	0.743 781	0.353 836	0.73
5	0.100 000	0.022 401	0.495 522	0.475 608	0.81
6	0.150 000	0.018 831	0.257 028	0.673 029	0.86
+7 at CED	0.192 022	0.015 830	0.139 165	0.953 397	0.95

N.B.—Values of j_{DC}, unavoidably, only approximate.

curves of the inner surfaces of the tubular en-
ergent inlets or velocity generators, $\overline{mnDCm}$, of
D_C, and E_{1C}, which correspond to the divergent
f types A, B, C, D and E, are all shown on Plate
so the geometrical loci of the throat velocity
e acceleration factors, *j*, pertaining to these con-
ame as for the divergent receivers.
rgent receivers of the various types considered,
e end bases $\overline{CED}$ and $\overline{GHF}$ and the same length
ned, as above set forth, that they must all neces-
y effective in inducing an increased throat
r 2.3867 times the theoretical velocity due to the
ter column corresponding to the difference be-
P_1 and P_2, leaving friction out of consideration

as it is clear that the same convergent inlet of
e liquid stream is continuously checked so as to

$\frac{}{67}$ of the quantity of liquid that would be pro-

ple orifice in a thin plate of diameter $\overline{mn}$, under
, or through some equivalent inlet, the balance
having to return towards the source of supply
reserve pressure, would undoubtedly be capable
l supply required to increase the said theoreti-
times when used in connection with any one
eivers, A, B, C, D, provided always the shape
ich that it will not fail to remain effective, by
communication of motion, over its whole length,
$\overline{HG}$. The angle of divergence of the sides may,
at in particular sections of some of the tubes to
ing full from end to end without a break, under
mall pressures. This would, no doubt, occur in
used resembling that of type C, in which the
uptly flared out near the lower or butt-end.
further investigation to determine which one of
vers can induce the greatest increase of throat
n connection with an inlet tube of suitable pro-
the degree of efficiency of any divergent re-
also governed, in a measure, by that of the
ch supplies the liquid.
onvergent inlet tubes or velocity generators,
apprehend that their sides might converge too
eir unbroken effectiveness ; but the velocity of

efflux afforded by such tubes when used by themselves, mig
be diminished so as to be materially less than the the
velocity due to the effective head, and the throat velocity
complete convergent-divergent ajutage correspondingly redu

On the other hand, owing to the imperfect fluidity of all
liquids, the incessant checking of the free flow of a liquid in
gent tubes, combined with the increased friction developed
their sides, must induce complex mutual interferences
rapidly revolving or oscillating liquid particles which imp
bodily translation of the liquid during the transformation
momentum—comparatively more than in cylindrical or di
tubes, besides which, on account of the mechanical difficulti
overcome in constructing convergent tubes of the precise
determined by computation, interruptions are often likel
caused in the normal flow by unavoidable imperfections in
tubes, that have also to be reckoned with in establishing the
cal proportions of an inlet. Therefore, in order that the ful
required to satisfy the draft created by the divergent
$\overline{CDGFC}$ may be assured it is necessary from a practical
view, that this tube be connected with the reservoir R
conoidal inlet capable of increasing the throat velocity
n or 2,3867 times, the same as the inlet $\overline{CDNMC}$, but which is
and has sides converging at a greater angle than the said

That is to say: the inlet of maximum efficiency for use
nection with the receiver $\overline{CDGFC}$, will be found to be a co
mouth piece such CDn'm'C, shown on Plate 15 by lines of a
dots and dashes—possibly one even still shorter—which
sponds to a divergent receiver $\overline{CDG'F'C}$ of the same theoret
ciency n with respect to the transformation of vein-momen
receiver $\overline{CDGFC}$, but of diminished length EH' as compared

By making EH', the length of the receiver $\overline{CDG'F'C}$, equa
foot, equation (I_E), (See page 287), gives: $G'H' = y'_{EI} =$
0.068190 ft. We have also $k' = \frac{F'H'}{CE} = \frac{0.06819}{0.01583} = 4.30764$, an
tions (L_{EI}), (M_{EI}) and (N_{EI}) (see p. 293-294) give under t
cumstances: $l'' = \overline{E}e' = 0.140197$ ft., $\overline{m'e'} = 0.029313$ ft. and
0.027093 ft., where x_1'' denotes the distance in rear of $\overline{m'e}$
the shortened convergent inlet E'_{IC} corresponding to E_{IC}
infinitely wider.

In order to secure the best results, as regards transform
vein-momentum and the production of correspondingly i
throat velocities and diminished throat pressures, the profil

ce connecting the up-stream section of a water
er reservoir R_1, with a divergent receiver,
used in the small McGill meter, should, there-
ide more nearly with the figure $\overline{Cm'W''Z''n'DC}$,
lines of alternate dots and dashes on Plate 15,
$\overline{CmWZnDC}$; the exact size and shape depend-
length found to be most suitable for $\overline{EH'}$ and
tube adopted, whether A, B, C, D or E, or any

above set forth, the proportions and forms of
ajutages of types A_C, B_C, C_C, D_C, which are
the requisite volumes of liquid to satisfy in a
d without causing any accumulation of super-
reserve pressure, the draughts induced respec-
g divergent receivers of types A, B, C, and D,
ed that the sectional area of the up-stream por-
as very great in comparison to the sectional
he meter. In the Venturi, however, as at pre-
ratio of the sectional area of the pipe to that
equal to from 9:1 to 18:1 and, therefore, evi-
derable in any case, but comparatively rather
Mr. Herschel's standard meters.
en that while the receivers A, B, C, D, are pre-
dition as the divergent lower cone of the Ven-
g inlets A_C, B_C, C_C, D_C are only approximately
as the convergent upper cone.
that during the passage of the water through
gent ajutage $\overline{W'mCFGnZ'W'}$, none of the
possesses when flowing through the orifice $\overline{mn}$
flow is permanently established, the component
tors of the said momentum being transformed
the other,—it is clear that in order that the
ge of the unintercepted pipe or main might be
the said ajutage or meter, (or nearly so), not-
ratio of pipe section to throat section is com-
theoretical hydraulic, or longitudinal velocity
m pressure P'_2 to which the corresponding
pressure P'_1 becomes reduced should be such,
d produce in the orifice $\overline{mn}$ the requisite
r longitudinal velocity v_{mn}, to create in the full
$\overline{WZ}$ of the pipe the velocity v_{FG} or v_{WZ}, which
ious to the insertion of the convergent-diver-
nstitutes the meter. That is to say: $(P'_1 - P'_2)$

should be nearly equal to the decrease in theoretical heig
the diminution in velocity of translation from v_{mn} in the c
to v_{FG} in the cross section $\overline{FG}$ or to v_{WZ} in the cross sec
divided by the ratio i_v of the total head P'_1 to the portio
head which is effective in generating motion of translati
said orifice or entrance $\overline{mn}$, as will be more fully exp
Chapter V. (See page 331) viz., we should have:

$$\left(P'_1 - P'_2\right) = \frac{\left(v_{mn} - v_{WZ}\right)^2}{2gi_v}$$

Now, considering that the velocity of translation v_{mn} i
fice $\overline{mn}$ is equal to the velocity in the cross section $\overline{WZ}$ mul
the inverse ratio $\frac{\overline{WZ}^2}{\overline{mn}^2}$ of the areas of the corresponding
cross sections of the same stream, and for the same reas
throat velocity v_{CD} multiplied by $\frac{\overline{CD}^2}{\overline{mn}^2}$, we have for the t
effective or velocity producing pressure $(P'_1 - P'_2)$ in tern
velocity v_{WZ} in the full cross section $\overline{WZ}$ of the main, the ex

$$(P'_1 - P'_2) = \frac{v^2_{WZ}\left(\frac{\overline{WZ}^2}{\overline{mn}^2} - 1\right)^2}{2gi_v}$$

Again, considering that in one and the same permane
stream the velocity v_{WZ} in any cross section $\overline{WZ}$ must be
the velocity v_{CD} in any other cross section $\overline{CD}$ multiplied b
we have also for the said theoretical effective pressure (
in terms of the throat velocity v_{CD}, the expression:

$$(P'_1 - P'_2) = \frac{v^2_{CD}\left(\frac{\overline{CD}^4}{\overline{WZ}^4}\right)\left(\frac{\overline{WZ}^2}{\overline{mn}^2} - 1\right)^2}{2gi_v}$$

throat velocity v_{CD} by its equivalent expression
, viz., by $C_1\sqrt{2g(P_1-P_2)}$, where C_1 and $(P_1-$
derived directly from experiments, the theore-
ocity generating head $(P'_1-P'_2)$ is found to be
arrow limits by the expression:

$$(P_1-P_2)\left(\frac{C_1^2}{i_v}\right)\left(\frac{\overline{CD}^4}{\overline{WZ}^4}\right)\left(\frac{\overline{WZ}^2}{\overline{mn}^2}-1\right)^2 \qquad (\triangle_2)$$

e theoretical effective hydraulic head $(P'_1-P'_2)$
he actual hydraulic head (P_1-P_2), we should
ssible:

$$\left(\frac{C_1^2}{i_v}\right)\left(\frac{\overline{CD}^4}{\overline{WZ}^4}\right)\left(\frac{\overline{WZ}^2}{\overline{mn}^2}-1\right)^2=1 \qquad (\triangle_3)$$

---

foot steps of the illustrious Italian philosopher,
d his water meter, the inventor of the "Venturi"
devise an apparatus by means of which practi-
me of water passing in a cylindrical water main
ow through a contracted section of pipe or a
quid approaches through a rapidly converging
way of a gently expanding conical off-take or
he parts are so proportioned that the maximum
on possible would be generated in the inlet if
at by the addition of the divergent-receiver the
e would become unbalanced to the extent re-
increased throat velocity that would invariably
nearly as practicable, to the theoretical velocity
esponding to the difference between the result-
at pressure and the pressure at the entrance to
t. In this endeavour, Mr. Herschel did not,
ncern himself, at first, about any final loss of
so called), that might be experienced by using
loss being viewed by him more in the light of
back of secondary importance, caused by exces-
nical imperfections, etc., than as an essential
king of the meter, as it has been shown to be.

While it appears that a properly shaped conoidal inlet t
the type E_{1C} above defined, or more likely a corresponding
and broader inlet such as W″m′CDn′Z″W″, may afford, whe
independently, a steady outlet velocity equal to, say from
0.98 of the theoretical velocity due to the head, h, correspon
the difference between the entrance and outlet pressures,
comparatively large range of pressures of heads, provided th
of pipe to throat section is considerable, when such a con
tube is used in connection with a divergent receiver, the ef
of the combination cannot be quite as uniform or constant.

The investigations made thus far, as above set forth, show
that the factor of efficiency of a given combination of a con
inlet with a divergent receiver, as regards the drawing of
through the throat or contracted passage connecting such tube
a reservoir or section of water main R_1 under a given pressur
another section R_2, where a lower pressure P_2 obtains
necessarily vary with the diameter or area of the throat, CE
the quantity of water passed through in the unit of time or t
ference of pressure $(P_1 - P_2)$ or hydraulic head h_e brought i
quisition for such purpose.

V. Applications of New Theory of Flow Through Aju

We may assume provisionally that the convergent velocit
rator or inlet of the McGill meter has within tolerably
limits the same supplying power as the frustum of con
generated by the revolution of a zone of the curve determi
equation (M_{EI}) (See page 293), about its longitudinal axis,
one of the four corresponding shortened convergent conoida
of types A_C, B_C, C_C, D_C, which have been shown to posse
ably about the maximum delivering efficiency that can be
when used in connection with a divergent receiver having th
proportions as that of the McGill meter. In such case it is
that if the relation which the proportional acceleration or
i_v of the circular freely contracted vein during cons
infinitesimal periods of up-stream and down-stream ethereal
sions or oscillations of liquid particles bears to the intensity
pressure in the reservoir or the corresponding velocity of t
tion and the diameter of the orifice in a thin plate through
the vein is projected, was known, equation (H_G) on page 27
be conveniently applied as it stands—after replacing x by l an

o $\left[\begin{matrix}\text{coeff veloc}\\ \text{Sect CED}\\ \text{of inlet}\end{matrix}\right]$ its proper value for determining at least

(overlooking now the fact that the ratio of pipe sec-
section is not so great as it should be) the throat
said small McGill meter, by taking from a table or
s the proper value of i_v for each pressure $(P_1 - P_2)$
into requisition, and for a conoidal mouth-piece of
as that used.

alues of i_v in veins of ordinary diameters formed
s of various intensities can be arrived at, at least ap-
n the following manner.

what may be the absolute rate of bodily advance, or
tion in space, of a freely contracted liquid vein, as
its size and the pressure by which it is generated
ernment of the ethereal force, f, acting along its
nsecutive increments of time, dt, alternately with the
ities 1 and i_v, while the direction of the resultant of
oscillations or orbital movements in each elementary
reversed from down-stream to up-stream, and vice
nd of a great space of time, T, after the flow has been
stablished, as herein above explained in chapter II.
the final result of the action of the force f, with these
tensities, must be the production of an increase in
formation of the vein, during its passage from the
ifice, where it originates, to a plane at a very great or
e from the said orifice, in the ratio of $\sqrt{i_v}$ to $\sqrt{1}$.

st have : $i_v = \frac{v^2_{\text{orif.}}}{v^2_{\text{cont.}}} = \frac{r^4_{\text{cont.}}}{r^4_{\text{orif.}}}$, where $v_{\text{cont.}}$ and $r_{\text{cont.}}$
ectively, the velocity in and the radius of the section
ontraction of the vein, which obtains theoretically at
ance from the orifice, but practically at a distance
ameter of the vein or so, and where $v_{\text{orif.}}$ denotes the
ux in the circular orifice in a thin plate and $r_{\text{orif.}}$ the
aid orifice. And if we accept as an axiom of hydrau-
elocity of any contracted vein at its cross section of
raction, cannot exceed that due to the total height, h_e,
olumn, which caused the formation of that vein, and
height of the water column due to the velocity which
s in the plane of the orifice in which the vein origi-
ut: $i_v = \frac{h_o}{h_e}$

Again, when h_e is very small, the actual co-efficient of velo

$\begin{bmatrix} \text{coeff} \\ \text{veloc} \\ \text{orifice} \end{bmatrix}$, in the plane of the orifice, as determined by well condu

experiments, agrees closely with the theoretical co-efficient:

$\begin{bmatrix} \text{coeff} \\ \text{veloc} \\ \text{orifice} \end{bmatrix} = \sqrt{.4721} = 2 \left[\frac{\sqrt{5} - 1}{2}\right]$, where 0.4721 represents the frac

of the total head, h_e which should be effective in producing the v

city of translation proper to the said plane, according to C

alier Antonio Maria Lorgna's "*Phisico-mathematical theory of the*

tion of liquids issuing from orifices in reservoirs," published in 178

the fourth volume of the memoirs of the Italian Society of Scie

of which Lorgna was the founder and first president. The frac

0.4721 can, therefore, be taken to be the correct theoretical valu

$\begin{bmatrix} \text{coeff} \\ \text{veloc} \\ \text{orif.} \end{bmatrix}$ when the head h_e is infinitely small, or nearly e

to 0 in comparison to the diameter of the orifice.

Finally, the available results of experiments made by var

hydraulicians go to show that i_v varies inversely as the square

of the velocity of the flowing liquid, or the fourth root of the p

sure or head, h_e, plus some constant quantity k, and, moreo

that its value for a vein projected through an orifice of about

an inch in diameter under a head of one foot, may be taken at

and that when the head on the same orifice is increased to 25

i_v decreases to nearly 0.33.

We have therefore the relation:

$$(\sqrt[4]{h_e} + k) : (\sqrt[4]{h'_e} + k) :: i'_v : i_v \quad \text{whence:}$$

$$(h'^{\frac{1}{4}}_e + k)\, i'_v = (h^{\frac{1}{4}} + k)\, i_v$$

where h_e and h'_e denote any two effective heads or pressures,

constant to be determined, and i'_v and i_v the intensities of

force f, during the up-stream excursion period of the molecules,

responding to the pressures or heads h'_e and h_e on an orific

known size.

Replacing in equation (O): $h_e^{\frac{1}{4}}$ by $\sqrt[4]{0 \text{ ft.}}$, i_v by 0.4721, $h_e^{\frac{1}{4}}$ by $\sqrt[4]{}$

and i_v by 0.400, we obtain:

$$k = 5.555$$

(O) gives us for i_v the expression :

$$i_v = \frac{2.622515}{5.555 + \sqrt[4]{h'_e}} \qquad \text{(P)}$$

of equation (P), the writer computed the following of approximate values of i_v for small veins of from h, or, say, about half an inch in diameter, projected pressures h'_e up to 40 ft.; the ratio $\frac{h_e}{2r = 0.50 \text{ inch}}$ of head r $2r$ being also indicated.

TABLE F.

et.	i_v	$\frac{h_e}{(2r = 0.50 \text{ inch})}$
	.4721	0
8	.4546	0.05
6	.4514	0.10
4	.4493	0.15
	.4464	0.25
	.4420	0.50
	.4365	1
	.4304	2
	.4264	3
	.4234	4
	.419	6
	.412	12
	.404	18
	.400	24
	.394	36
	.389	48
	.382	72
	.376	96
	.370	144
	.360	216
	.353	288
	.347	384
	.342	480
	.337	600
	.332	720
	.325	960

ituting l for x and l' for x' in equation (H_G) (See above stated, we obtain:

$$\left[\begin{matrix}\text{veloc.}\\ \text{sect. CED}\\ \text{ajutage}\\ \text{ABDGFCA}\\ \text{or}\\ \text{WCFGDZW}\end{matrix}\right] = \frac{\sqrt{2gh\left\{\dfrac{\left(i\sqrt{s_v+l+l'} + \sqrt{i_v(s+l+l')}\right)(s+l')}{\sqrt{i_v(s+l)} + \left(\sqrt{i_v s+l}\right)\left(\dfrac{s'^2}{(s'-ml')^2}\right)}\right\}}}{\sqrt{s+l+l'}} \times \left[\begin{matrix}\text{coeff v}\\ \text{sect C}\\ \text{inle}\\ \text{ABD}\\ \text{or}\\ \text{WZD}\end{matrix}\right]$$

(H

in which formula the symbols l, l' and s have the values air given, viz.: $l = 0.03166$ ft., $l' = 0.855$ ft., and $s = 0.0125$ ft., while $(P_1 - P_2)$.

As regards the co-efficient of the velocity of efflux from the cal inlet or velocity generator of the meter $\left[\begin{matrix}\text{coeff veloc}\\ \text{sect DEC}\\ \text{inlet}\\ \text{WZDCW}\end{matrix}\right]$, owin the complex nature of the case, the writer adopted in the absen more definite information, uniformly 0.92 for its mean value fo effective pressures $(P_1 - P_2)$ used in the McGill experiments u discussion, where the discharge took place invariably under w The writer finds that according to Fig. 1 of M.M. Coker and St land's paper, the sides of the inlet of the small Venturi meter by them converge at an angle of about 26°, the actual angle is, ever, as already observed, probably nearly the same as in Mr. schel's large meters, viz., 21°. (See foot note on page 266). Ac ing to MM. D'Aubuisson and Castel's experiments with co gent tubes 1.55 centimeter (0.61 inch) in diameter at the s base, discharging in air under a pressure or head of 3 m (10.883 feet), such a mouth-piece gives a velocity of efflux equ $.919\sqrt{2gh_e}$ and a final velocity of vein equal to $.971\sqrt{2gh_e}$; denoting the full effective head. It is probable that during the sage of the contracted vein, from the small base proper of the u cone, through the conoidal part of the inlet where the straight are rounded to make an easy junction with the throat, the li vein increases in velocity so as to reach the maximum of .971 recorded by the French experimenters, last named, in the th This velocity the writer reduced to $0.92\sqrt{2gh_e}$, to allow for caused by efflux under water through the McGill meter instea air, unavoidable imperfections in that small instrument; etc.

Dividing equation (H'_{GA}) by $\sqrt{2gh}$, and replacing in the quo the constants by their values, as above established, we obtain fo

ocity of efflux at the throat, $\overline{CED}$, of the ajutage, its equivalent Venturi meter $\overline{WZDGFCW}$:

$$\frac{\sqrt{(\sqrt{0.0125\,i_v+0.8867}+\sqrt{0.8991\,i_v})^2(0.04417)}}{\sqrt{(\sqrt{0.04417\,i_v}+(\sqrt{0.0125\,i_v+0.0316})(0.054592))^2}} \times$$

$$\times \left[\begin{array}{c}\text{coeff veloc.}\\ \text{sect. } \overline{CED}\\ \text{inlet}\\ \overline{WZDCW}\\ =0.92\end{array}\right] \qquad (Q)$$

the value of i_v varies with the effective head h_e P_2) as shown in Table F.

hich here follows, the experiments made by Dr. trickland in 1902, are grouped into sets of from rein the throat velocity varied within very narrow ne by these gentlemen; but the said groups of ntered here in the order of the pressures ($P_1 - P_2$). of the columns explain themselves, with the excep- olumn 5, having reference to the second line of this column, the meaning of which is indicated

ed that in calculating co-efficients C_2, the loss of bona fide friction in the divergent receiver was sideration. There was, of course, no occasion for ately the loss of velocity from the same cause in ergent cone, as this loss forms part of the reduction 0 to 0.946, made in the co-efficient of efflux in air ent tube, as determined by M.M. D'Aubuisson and the writer has further reduced to 0.92, for efflux

and, there was no allowance made for the increase , which must have resulted from the velocity of supply pipe on the up-stream side of the meter, amounted to about 1-18 of the actual velocity at naximum contraction and to, say 6 per cent, rresponding to co-efficient C_2. As regards the re- stream caused by friction against the sides of the or lower cone, it can be placed approximately at gure as that which obtains in a cylindrical pipe

having a diameter equal to the mean diameter of this receiv
the same length, which is nearly 11 mean diameters in this in
Now the loss of velocity caused by friction in a cylindrical
pipe about 11 diameters long, varies according to the tables
efficients of velocities reduced by friction given in "Neville
draulic Tables, Co-efficients and Formulae," Third Edition, b
about 10 per cent. for the velocities corresponding to the
pressures (P_1—P_2) and 7 per cent., or less, for the velocities
sponding to the highest pressures (P_1—P_2) under which effl
place in Messrs. Coker and Strickland's experiments, as per T
So that, assuming that the pipes referred to in Neville's tab
as smooth a finish inside as the Venturi meter, which is not
however, if both the retardation caused by friction and the
ation in the stream due to the velocity of approach had bee
into account, the net result would have been a slight decr
perhaps from 1 to 3 per cent. in the values of the co-efficients
entered in Table G.

There can be no doubt, however, that the sides of ordinar
pipes offer a greater resistance to the free flow of the liquid t
sides of a well-finished Venturi meter; moreover, the influ
friction on the flow in a divergent receiver may be considere
two different points of view. Instead of causing reduction o
ity, friction may resolve itself in some cases, partly, if not e
virtually into an increase of pressure stemmed, thus assist
lateral communication of motion and tending to increase,
whole, the swiftness of the divergent vein, rather than to d
it, therefore the question: what are the proper small cor
that should here be applied to the co-efficients C_2, is an ope

The co-efficients C and C_1 deduced from the experiment
determined by Messrs. Coker and Strickland, as given in co
and 10 of Table G, evidently decrease on the whole as the h
crease, whether we consider (P_1—P_0) or (P_1—P_2), to be the
basis for the measurement of motion of translation in th
passing through the meter; but while the variations of C a
gradual, C_1 fluctuates in a very irregular manner. On t
trary, the co-efficients, C_2, computed with the aid of formula
and (Q) gradually increase, slowly but continuously, as the
heads or pressures (P_1—P_2) become larger, and the rat
or the total pressure ratios $\frac{P_2 + 33}{P^1 + 33}$ become smaller.

The "raison d'être" of these apparently conflicting theoret

	10	11
cients of velocity of efflux h meter at throat $\overline{CED}$.		
$\times$ $P_2)$	$C_1 = \frac{vel_{CED}}{\sqrt{2g \times (P_1 - P_2)}}$ Also: C_1^2	C_2 according to formulas (H'_G) and (Q). Also i_v for pressures ($P_1 - P_2$) according to Table F)
3	2.379	2.171
	5.660	0.4172
1	2.527	2.174
	6.406	0.4154
7	1.701	2.194
	2.893	0.4020
1	2.115	
	4.473	
6	2.010	2.197
	4.040	0.3988
6	1.968	
	3.873	
9	2.061	2.213
	4.244	0.3890
0	2.193	
	4.809	
2	2.275	
	5.176	
4	2.350	2.221
	5.522	0.3790
9	2.361	
	5.574	
7	2.298	
	5.281	
4	† 2.397	2.236
	5.746	0.3724
9	2.373	
	5.631	
9	2.349	
	5.518	
6	2.357	
	5.555	
4	2.317	
	5.368	
7	2.235	2.258
	4.995	0.3620
8	2.157	2.262
	4.653	0.3593
4	1.986	2.269
	3.944	0.3550
7	1.799	2.286
	3.236	0.3480

($P'_1 - P'_2$) according to

, and 5.310 ft. in No. 18.

. in No. 3.

lts appears to the writer to be clearly as follows.
ical co-efficients of efflux, C_2, have all been com-
othesis that the divergent pressure accumulator
for a fixed length $\overline{EH} = l'$ and that the degree of
vein issuing from the convergent conical mouth
e in all the experiments—the fluctuations of the

p-stream pressure P_1, to the down-stream pressure

olumn 8, and the discrepancies between P_0 and the
ion $(P_1 - (P_1 - P_2)\ C_1^2)$ as shown in column 6, in-
er hand, that the co-efficients, C_1 and C, apply to
s of varying effective lengths and to convergent
ferent degrees of contraction and supplying effi-
s of co-efficients, C_1, being now and then also
ntal variations in the last mentioned contraction,
losses of living force caused by friction against
eceiver, and possibly, also by some eddies formed

results entered in column 10, the combined effects
contraction and in the supplying power of the
e upper cone, friction developed at the sides of
formed in the same, etc., seem to have rendered
FC effective for its entire length, $\overline{EH}$, only in

ents No. 13, where for a ratio $\frac{P}{P_1}^2 = 0.386$, and a
o of 0.874, a throat velocity co-efficient $C_1 = 2.397$
effective pressure $(P_1 - P_1)$ was increased from
p of experiments No. 13, to 15.278 feet in group
tal pressure ratios decreased simultaneously from
pressure stemming power of the receiver in the
low, together with the discharging power of the
meter became reduced; the resulting throat velo-
$_1$ being lowered from 2.397 in group No. 13 to
. 21. In group No. 15, where the total pressure

832,—while the corresponding ratios in adjoining

are 0.863 and 0.844 respectively, the throat veloc-
l be) but 2.349 against 2.373 in No. 14, and 2.357
ghout the whole series of experiments extending
3 to group No. 21, the portion of the divergent
nained effective, was evidently gradually decreas-

ing in length, for the reason that the divergence of the r
proved, on the whole, too great for the hydraulic pressure
inlet and the supplying efficiency of the same.

The nearly constant values of C in Nos. 13 to 21 as per co
go to show, however, that the effect of this decrease in the
length of the receiver was, in a great measure, counterbalan
the increased contraction which obtained in the vein projecte
the conical inlet.

On the other hand, the continuously increasing values of
efficients C for experiments Nos. 13 to 1, would seem to indic
a receiver longer than $\overline{EH}$ was effective in increasing the ste
power of the stream and the throat velocity of the ajutage
said groups of experiments. In such event the down
pressures P_2 which were observed near the lower base, $\overline{GF}$
receiver would fall short of the full liquid pressures stemme
which correspond to the velocities generated in the throat
and there would likely be zones of eddy water between the
divergent vein and the sides of the pipe resulting from pu
determined in the theoretically imperfectly proportione
shaped convergent-divergent stream. But leaving these co
tions entirely aside, it is evident that the acceleration of the
in the throat at $\overline{CED}$ in excess of that which can be produc
receiver having the same divergence as $\overline{CDGFC}$ is impos
view of the fact that the water pipe is perfectly cylindrica
the base $\overline{FG}$ of this receiver.

By comparing, in groups Nos. 12 to 3, the co-efficients
column 10 with the co-efficients C_2 in column 11, it will be s
if amended co-efficients C_2 were computed for the said gr
experiments, with the aid of formula (H_G), on the basis of
$= 2.397$ in group No. 13, the new co-efficients C_2 would all b
to be larger, respectively, than C_1, and therefore the the
differences between the pressures at the upper and lower end
meter or the velocity generating heads, would be small
$P_1 - P_2$, and also the pressures P_2 smaller, respectively, t
theoretical down-stream pressures that would obtain if
momentum of the maximum quantity of water which an inl
right proportions and shape could deliver through the throat
$\overline{CED}$ with an up-stream pressure about equal to P_1, was tran
in the receiver $\overline{CDGFC}$ so as to increase the mass factor
expense of the velocity factor. Hence we must conclude
experiments 12 to 3 a portion of the momentum of the sai
tity of water remained untransformed or stored as reserve
and back water in the up-stream section R_1 of the main a

5, although remaining effective throughout its entire
ailed to be as powerful a momentum transformer as
riment No. 13, partly owing to the inefficiency of
inlet in supplying the volume of liquid required to
e draught induced by the receiver and partly owing
roportions of the latter in comparison with the shape

of experiments Nos. 1, 2 and 3, strong pulsations, a
large velocity of approach and other disturbances
so completely unsettled the regular conditions of flow
eter that the results obtained cannot be satisfactorily

of Table G it is shown that the minimum loss of
l velocity obtained in series of experiments No.
pressure ($P_1 - P_2$) observed to have been used up to
naintain the existing flow of water from reservoir R_1
bears to the pressure ($P'_1 - P'_2$) which should theo-
sufficient to produce the same flow through the meter,

o 0.8345—That is to say: $\frac{1}{.8345}$ or nearly 1.2 times the

ssure had to be brought into requisition, showing a
equal to 0.2 ($P'_1 - P'_2$) and a corresponding propor-
elocity represented by $\sqrt{1.20} - \sqrt{1} = 0.095$, which is
by friction developed against the sides of the meter,
y by imperfect proportions and conformations of
inlet and its divergent outlet.

me that in those experiments where the stemming
n transforming power of the meter proved to be a
results were practically uninfluenced by the defective
nd shaping of the receiver and the inlet as regards
elocity of translation induced in the said divergent
, however, is hardly possible—the whole loss of 9½
e velocity must have been caused by friction. This
to agree tolerably well with the indications afforded
ydraulic Tables co-efficients and Formulae," given
g to which the loss of velocity in the meter due to
should be from 7 to 10 per cent.—although there is,
a small velocity of approach that should be taken

ion, which in this case amounts to $\left(\frac{CN^2}{WZ^2} = 0.055\right) v_{cn}$

be asked how does it happen that the calculated vel-
t C_2 for group No. 13 is but 2.236, while the ex-
fficient is 2.397. The reason is two-fold. The writer

has already pointed out that there is considerable difficulty in
mining theoretically the precise value of the co-efficient of
from the convergent inlet or upper cone, on account of it bei
continuation of a cylindrical pipe having an area as small as 18
that of the throat. There is another reason, however. The valu
i_v used for computing the said co-efficients, C_2, taken from Ta
are those corresponding to velocities due to the pressures (P_1
which were, under the circumstances, considered sufficient for
approximation; but it is evident that when the meter
full operation efflux takes place from the upper cone with velo
corresponding more closely to those due to the pressures (P_1-
hence in taking i_v from Table F, $h_e = (P_1 - P_0)$, should have
used as the argument, the effect of which would have been to s
ly increase the values C_2.

By replacing in equation (H'_G) i_v by .3305, the proper valu
a head $h_e = 31.9$ feet, instead of using, as was done, 0.3724, the
corresponding to a head of 5.173 feet, co-efficient C_2 of group N
is found to be equal to 2.313 instead of only 2.236. A similar
would of course have been arrived at had the computed valu
$(P_1 - P_2)\ C_1^2$, viz., 29.723 ft., been taken as the argument for a s
approximation to C_2, instead of the observed pressure (P_1—
31.97 feet.

Although, as already stated, the combination WACFGDBZW
convergent with a divergent tube, which constitutes the Ve
meter, attained the full efficiency corresponding to the length,
simultaneously as regards discharging and pressure stemming
in group of experiments numbered 13 in Table G, if in order to
ther eliminate, in a measure, possible accidental irregular flu
tions we take the mean of the four values of the ratio $\frac{P_2}{P_1}$ i
four sets of experiments, numbers 13 to 16, where the efficien
the apparatus varied within very narrow limits, we arrive at
for a maximum value of $\frac{P_2}{P_1}$, which is only about 1 per cen
excess of the mean of the four values of i_v corresponding to
respective down-stream pressures P_2 in the same four grou
experiments, according to Table F. In view, however, of the
that Table F is applicable more especially in the case of a
projected through a simple orifice about ½ inch in diameter,
that the diameter of the large base of the effective portion o
divergent receiver measures over 1½ inches, the indications are

lue of $\frac{P_2}{P_1}$, is probably within less than 1 per cent.

corresponding to pressure P_2 in a vein having a o the said large base, and the maximum pressure stemmed by an up-stream pressure P_1 is, there- equal to $i_v P_1$.

ple relation, viz., $P_{2m} = i_v P_1$ holds good in general inations of conjugate convergent and divergent um momentum transforming power, so long

of the sectional area of the pipe to that of the

ufficiently large and the limits of the lateral com- otion are not over-stepped, the writer is not in a e, but he feels satisfied that under theoretically s, the said maximum pressure stemmed, P_{2m} is far undetermined, and perhaps more complex func- tream or stemming pressure P_1 and the ratio or $_v P_1$ or $(l-i_v)\ P_1$.* For as already intimated in e believes every increase in liquid pressure nied by a change in the initial, gyratory, or oscil- of the liquid particles, viz., must cause these ke place within limits differing from those deter- iginal pressure, and produce a corresponding in- idity of their orbital motions or oscillations of the the development of ethereal centrifugal or vibrat-

ng that in consequence of those mutual actions of les, when a vein advances into a convergent- e of maximum momentum transforming power, m, from the supplying reservoir R_1, or is formed fice in a thin plate in its side by virtue of the re P_1 obtaining in R_1, over one-half of this pres- perative in generating velocity of translation and e plane of the entrance $\overline{mn}$ to the ajutage, or in corresponding simple orifice—there is no apparent pressure P_2 accumulated in the receiving reservoir

---

cis' Lowell experiments with the divergent tube described on page t in a large receiving tank, the ratio $\frac{P_{2m}}{P_1}$ was $\frac{1.57}{2.75} = 0.57$, when the g power of the tube proved to be a maximum, viz., when the throat 2.43 under a hydraulic pressure $(P_1 - P_2)$ of 1.18 ft. The expression l to $1 - 0.386 = 0.614$, which would show a loss of about 8 per cent. of ated in the tube due to friction; etc.

R_2 should not similarly remain inoperative in checking the mo
tum of the vein formed in the said ajutage at the outlet $\overline{FG}$, as
as P_2 remains inferior to ½ P_1, or thereabouts.

If, for the sake of argument, we assume that $\frac{P_{2m}}{P_1} = i_v$ is co
for convergent-divergent ajutages such as the Venturi meter, v
inserted in pipe lines, we will in such case have $(P_1 -$
$= \frac{1}{i_v}(P_{2m} = P_2 - h_0)$ and, consequently, the proportion: $(P_2 -$
$(P_{2m} = P_2 - h_0) :: \frac{1}{i_v} : 1$; hence also dividendo: $(P_1 - h_0) - (P_{2m} = P_2$
$(P_{2m} = P_2 - h_0) :: (\frac{1}{i_v} - 1) : 1$, whence we deduce :

$$(P_{2m} = P_2 - h_0) = i_v (P_1 - h_0) = \frac{(P_1 - P_2)}{\left(\frac{1}{i_v} - 1\right)}$$

where P^2_m denotes the maximum hydraulic pressure that ca
stemmed by the up-stream hydraulic pressure $(P_1 - h_0)$, viz.,
total pressure P_1, minus the dead or hydrostatic pressure, h_0.
that in general in convergent-divergent ajutages of maxi
momentum transforming efficiency, the excess of any up-st

pressure P_2 over $\frac{(P_1 - P_2)}{\left(\frac{1}{i_v} - 1\right)}$ as also the excess of any up-stream

sure P_1 over $\frac{1}{i_v} \frac{(P_1 - P_2)}{\left(\frac{1}{i_v} - 1\right)} = \frac{(P_1 - P_2)}{(1 - i_v)}$ would simply represe

hydrostatic or dead pressure which does not materially affec
stemming power of the liquid vein. And, according as the tota

stream pressure P_1 would be greater or less than $\frac{P_1 - P_2}{1 - i_v}$,

drop from P_1 to the pressure P_2 which obtains at the d
stream end of the meter, would have to fall short of or exceed
minimum of $(1 - i_v)\ P_1$; but in no case would the bulk of
loss of head, or pressure, be caused by friction. The greater pa
or nearly all, the so-called lost head $(P_1 - P_2)$ has invariably t
expended or utilized, in drawing through the contracted throa
portion of the entire volume of water carried by the uninterce
main of uniform cross section which can be passed through
meter, and hence, it seems to the writer, the drop in the pre
from P_1 to P_2 constitutes at least as rational a basis for the m
urement of the accelerated motion of the stream in that thro
$(P_1 - P_0)$; but it affords no better indication of the loss of head
to the resistance of friction than this last variation of pressure.

roximate values of $P_{2m} = \frac{P_1 - P_2}{\left(\frac{1}{i_v} - 1\right)}$ entered in column 5,

in groups of experiments Nos. 12 to 3 and 18 to 21, P_{2m}

an P_2, for the same reason that C_1 and $\frac{P_2}{P_1}$ are smaller

groups of experiments, than their respective mean values
l 0.383 in the intermediate groups of experiments Nos. 13,
16. In groups Nos. 18 to 21, the portion of the receiver
ffective in each experiment, is clearly shorter than the
tive length corresponding to groups Nos. 13, 14, 15 and
roups Nos. 3 to 12 the observed down-stream pres-
fall short, respectively, of the full liquid pressures, P_{2m}
e stemmed by P_1 because, as already pointed out, the
f water which the imperfectly proportioned inlet $\overline{WCDZW}$
of delivering in a given time under the pressure P_1 in
f the groups of experiments Nos. 12 to 3, is sensibly small-
arison to the pressure, than the volume of water supplied
conditions of flow obtaining in Nos. 13, and because the
s and shape of the receiver $\overline{CDGFC}$ are only imperfectly
ransform the momentum of the liquid which the said inlet
of supplying, for which reasons ajutage $\overline{WCFGDZW}$ proved
less efficient in transforming momentum and stemming
han in Nos. 13. the same as in experiments Nos. 14 to 21,
nding that it remained effective throughout its whole

iter next undertook to determine with what measure of
uation (H_G) could be applied in computing the values of

ocity co-efficient $C_1 = \frac{v_{CED}}{\sqrt{2g(P_1 - P_2)}}$ etc., under conditions

ch as those which obtained with some of the experiments
Mr. Clemens Herschel in 1887, with a Venturi meter in-
a 1-foot water main.

, 1887, experiments were undertaken at Holyoke under Mr.
direction with a Venturi meter applied to a 1-foot water
ch are recorded with full particulars respecting the meas-
made and the results obtained, in Table No. 1, near the
his pamphlet of some 55 pages (not numbered), entitled
turi Meter," published in 1893 by the Builders Iron
Providence, Rhode Island; the experiments being num-
1 to 77.

mensions of the essential parts of the meter used for these
ts appear to have been nearly as follows :

1o.—Upper cone, including junction with throat:

Length, 1.890 feet.

Angle of convergence of sides, 21 degrees.

Diameter at junction with throat, 0.3316 ft.

Diameter of large base, 0.991 ft.

2o.—Lower cone including throat proper—which latter effectu forms part of the divergent receiver; being divergent in comp son to the freely contracted liquid vein issuing from the upper c or mouth-piece:

Length, 7.867 feet.

Angle of divergence of sides, 5 degrees.

Diameter of throat at upper end, 0.3316 foot.

Diameter of lower base 0.992 foot.

From Messrs. d'Aubuisson and Castel's experiments with c vergent tubes, it appears that, as already stated, the co-efficient efflux from a tube, the sides of which converge at an angle of 21 grees is but 0.92, while the final velocity attained by the freely c tracted vein, after leaving the convergent tube has a co-efficient 0.972; that of the theoretical velocity due to the head being un or 1.

It has been assumed by the writer that the maximum veloc due to the head is obtained in the throat of the small meter, there is no reason why this should not also be the case for large meters, but the co-efficient of velocity of efflux was here v probably somewhat larger than .920, say: .935. Moreover, the of velocity due to efflux under water instead of air, small defe in the instrument, etc., was also in all probability less than for small meter, say: 0.025 in place of 0.05 of the theoretical veloc So that for the meter suitable for a one-foot main, the co-effici

of efflux at the upper end of the throat $\left[\begin{smallmatrix}\text{coeff veloc}\\ \text{small base}\\ \text{inlet 1 ft. meter}\end{smallmatrix}\right]$ is proba at least 0.96, as compared to 0.92 for the small meter used in McGill experiments, when the ratio of pipe section to throat sect is considered to be very great, as was done in the case of the sn meter.

As here, however, the velocity of approach to the meter in one-foot pipe amounts to as much as $\frac{(0.3316)^2}{(0.9910)^2} = \frac{0.1100}{0.9821} = 0.112$ the throat velocity, the co-efficient, 0.96, was increased to 0.9 $(1+0.112)=1.0675$, in order to make up, in a way for this extra vel ity. Moreover, considering that practically all loss of head at caused by friction may resolve itself into loss of head at lower end of the meter, as already observed, no deduction was m from this last value of the co-efficient of efflux from the converg inlet on account of the friction generated in the receiver.

o put, the same as in the case of the small McGill risk of erring materially: $\overline{OE} = l = 0.3316$ ft., $\overline{AB} =$ 0.4145 ft., $s = 0.6r = 0.12$ ft. And we have by actual $= \left(\frac{0.3316}{2} = 0.6158 \text{ ft.}\right)$, $l' = 7.867$ ft., and $r' + ml' =$ ft. From these dimensions we deduce: $\frac{r'^2}{(r'+ml')^2} =$ 4, $s+l+l' = 8.3186$ ft., $s+l = 0.4516$ ft., $l+l' = 8.1986$ ft. $\frac{'+ml'}{r'} = 2.9976$.

ivide equation (H_G) (see page 272) by $\sqrt{2gh}$, and in eplace the constants by their approximate values as d. we obtain for the co-efficient of velocity of efflux of a meter applicable to a 1-foot main:

$$\sqrt{\frac{(\sqrt{0.12\,i_v}+8.1986+\sqrt{8.3186\,i_v})^2(0.4156)}{\{\sqrt{0.4516\,i_v}+(\sqrt{0.12\,i_v}+0.3316)(0.11174)\}^2}} \times \frac{}{\sqrt{8.3186}} \times \begin{bmatrix}\text{coeff veloc}\\ \text{throat inlet}\\ \text{1 ft. meter}\\ = 1.0675\end{bmatrix} \qquad \text{(R)}$$

alue of i_v in the large vein under consideration, it ned, in the absence of more definite information on the $_v$ remains constant for efflux under the same head, in racted veins, large and small, viz., say veins measur- an inch to eighteen inches or so in diameter, and es given in Table F were used as they stand in all ons made whether in connection with experiments small or large meter. This hypothesis needs to be y be found that it is not strictly true, but it is suffi- for the present purpose.

hich here follows contains a selection of ten typical rom those recorded in Table I of Mr. Herschel's e referred to; in this table also, the same as in Table ental measurements and results have been entered in he pressures (P_1—P_0) and (P_1—P_2).

glance that in Table H the co-efficients C and C_1 de- e experimental data determined by Mr. Herschel at 87, do not increase, on the whole, as the heads de-

crease, as appeared to be the case at first sight, for the correspondi co-efficients afforded by the experiments made at McGill by Coker and Mr. Strickland in 1902. Moreover the fluctuations of seem here to be, if anything, more irregular than the variations C_1, contrary to the showing of Table G; as a matter of course, steadily increases with the effective head in Table H, the same as Table G. We notice also that C_1 attains a maximum value of 2.6 in Holyoke experiment No. 50, near the centre of the series of Ta H, which maximum may be considered to correspond to the ma mum of 2.397 of group 13 in Table G, and explained in a simi manner.

In the said experiment, No. 50, or No. 5 of Table H, the combi effect of changes in the contraction of the vein formed in the up cone, friction against the sides of the meter; eddies formed in same, etc., was apparently to render the receiver, CDGFC., effec very nearly or precisely for its whole length, EH, the throat velo generated being 2.641 times as large as that due to the effect pressure ($P_1 - P_2 = 1.900$ feet) and P_{2m} the hydraulic press stemmed, approximately 1.252 ft.; taking for granted that P_2

$\frac{P_1 - P_2}{\left(\frac{1}{i_v} - 1\right)}$ is approximately correct in this case also.

Mr. Herschel's receiver also probably remained effective nea from end to end in experiments Nos. 6 and 7, notwithstanding t the effective pressures rose from 1,900 feet for No. 5 to 5,600 for 7, and the total pressure ratios decreased from .957 to .875; it evidently ceased to be effective for its full length, in experime Nos. 8, 9, and 10, where ($P_1 - P_2$) rose from 5.600 to 11.056 feet, the total pressure ratio $\frac{(P_2 + 33)}{(P_1 + 33)}$ fell from .873 for No. 7, to 0 for experiment No. 10, because the divergence of the receiver on the whole, too great for the effective pressure which obtai and the degree supplying power of the inlet.

The receiver was also less powerful as a momentum transfor in experiments Nos. 4 to 1 than in Nos. 5, 6 and 7, for the same son as the receiver of the McGill meter failed to retain its rela maximum efficiency in groups of experiments Nos. 12 to 3 of T G, viz., partly owing to the inefficiency of the convergent inle supplying the volume of water needed to satisfy the full drau which the receiver is capable of producing, and partly owing to unsuitable proportions and conformation of this receiver in altered conditions of the flow.

The reason of computed co-efficient C_2 turning out to be sma in experiment No. 5 (50), than the corresponding co-efficient C_1, duced from the experimental data, viz., only 2.382 instead of 2.64

10	11
ients of velocity of x through meter throat CED.	
$C_1 = \frac{Vel_{CED}}{\sqrt{2g\,(P_1 - P_2)}}$ Also: C_1^2	C_2 according to formulas (H'_G) and (R). Also: i_v for pressures ($P_1 - P_2$ according to Table F.
1.677	2.304
2.812	0.4464
2.016	2.308
4.064	0.4424
2.493	2.356
6.215	0.4120
2.484	2.368
6.170	0.3990
‡2.641	2.382
6.975	0.3900
2.503	2.390
6.265	0.3770
2.481	0.403
6.155	2.3710
2.255	2.418
5.085	0.3650
2.192	2.421
4.805	0.3630
1.868	2.4340
3.463	0.3550

.849 and in No. 10 : 2.846.

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$$\frac{P_1 - P}{\left(\frac{1}{i_v} - 1\right.}$$

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already given in connection with groups of McGill 13. By replacing in equation (R), i_v by 0.352, the a head $h_v = 13.20$ feet, instead of taking, as was alue corresponding to a head of 1.900 feet, co- 5 (50) is found to be equal to 2.442. The whole f the difference between 2.641 and 2.442 could caused by an unavoidable lack of accuracy in 75, the co-efficient of velocity of efflux from the nt conical ajutage constituting the velocity gene- end of the meter; but in the present case the om the general run of the discrepancies $(P_1 - P_0)$ etween the differences $(P_1 - P_0)$ of the actual pres- ulic heads at the up-stream end, and the pressures of the meter, as indicated by the gauges, and the C_1^2 due to the mean throat velocity, as deduced ental data which are entered in column 6 of lainly that from some unexplained cause the $l._{DEC}$ was abnormally high in experiment No. 5, the throat velocities determined for the adjoining Nos. 4 and 5, and that therefore the co-efficient be vitiated by some accidental disturbance.

cumstances, however, it is clear that values of C_2 eans of equation (H'_G) the same as those given in can only be approximately correct, considering d throat velocity can never be exclusively the nation of momentum while the ratio $\frac{\Pi \overline{FH}^2}{\Pi \overline{CE}^2}$ of the section of the cylindrical pipe to the area of the he throat remains a finite quantity.

he throat velocity co-efficient n for a convergent- similar to Mr. Herschel's meter when used in con- ery large reservoir R_1, was determined by the of equation (J'_K) and found to be 2.2157, and he ratios $\frac{(P'_1 - P'_2)}{(P_1 - P_2)}$ given at the foot of Table d by means of formula $(\triangle_2)$ (page 319). These that assuming the relation $P_{2m} = \frac{P_1 - P_2}{(i_v^1 - 1)}$ to hold ely also in the case of Mr. Herschel's large ot main with a throat section as large of the

cross section of the main, only say from $\frac{1}{4.85}=0.21$ to $\frac{1}{1.84}=0$

the total effective pressure ($P'_1-P'_2$), which is needed to trans
the whole momentum of the volume of water carried by the
so as to secure outlet and inlet velocities through the meter
to the velocity of the stream flowing through the clear pipe,
brought into requisition. If, therefore, we increase the said r
by say, 20% in order to eliminate approximately the loss of he
pressure due to friction, it would appear that only a fracti
the momentum of the stream flowing in the unintercepted
varying roughly from $\sqrt{0.26}=0.51$ to $\sqrt{0.65}=0.81$, was transfo
in the meter so as to increase the velocity of the moving liqu
the expense of the mass. A balance fluctuating roughly bet
19 and 49 per cent. of the total momentum of the stream tha
flow through the free cylindrical water main, according t
length of receiver which happens to be effective, remains the
to be accounted for, if however, as appears likely, in large m
the value of P_{2m} is intermediate between $\frac{P_1-P_2}{\left(\frac{1}{i_v}-1\right)}$ and $\frac{P_1-P_2}{\left(\frac{1}{1-i_v}-1\right)}$,
results will have to be amended accordingly. According t
views of the writer, as herein above expressed, a portion o
balance of momentum unaccounted for by the difference (P_1
between the up and down-stream pressures P_1 and P_2, is repres
by an increase in the motion of translation of the liquid par
imparted, as it were, in parallel lines, viz., without the pre
in the meter being affected thereby, save by the additional frict
resistance generated, and the remainder of the momentum req
to make up the said balance is represented by liquid maintain
a relative state of overflow in the reservoir of supply or up-st
section R_1 of the water main. The fluctuation of the ratios $\frac{P}{P}$
between 0.8345 and 0.389 indicated at the foot of Table G
obtained in the McGill meter would be accounted for by the
in a similar manner. The computations of the numerical valu
the ratios $\frac{P_1-P_2}{P_1-P_2}$ undertaken so far, are, on the whole, only t
tive, the whole matter needs to be more deeply and systemati
investigated.

F BERNOUILLI'S THEOREM FOR FLOW THROUGH VENTURI METER.

for the sake of argument, that, as may be believed
ous application of Daniel Bernouilli's fundamental
ulics is all that is required to account satisfactorily
s under which a stream of water flows through a
what may be its shape and size, and hence also
i meter, which is, after all, only a section of pipe

nay be enunciated thus: *In a permanent stream of rictionless conduit, the difference between the heads due to btain in any two cross sections of the conduit is equal to the the centres of gravity of these sections, minus the difference the up-stream and down-stream velocities. In any conduit the head due to the pressure, plus the height due section, plus the height of the centre of gravity of the section ntal plane, must therefore form a total height, which is a*

fact that the centre of gravity of all the cross sec-
are, as a rule, in one and the same horizontal line,
ations should therefore hold good, viz., we should

$$\frac{v_1^2}{2g} + P_1 = \frac{v_0^2}{2g} + P_0 = \frac{v_2^2}{2g} + P_2 \qquad \text{(S)}$$

denote respectively the up and down stream
the throat velocity of the ajutage which constitutes
$_1$, P_2, P_0, the corresponding pressures.
ge Holyoke meter applicable to a cylindrical pipe
eter we have also the relation:

$$v_1^2 = v_2^2 = 0.112\ v_0^2 \qquad \text{(T)}$$

McGill meter inserted in a cylindrical pipe 1.626
er:

$$v_1^2 = v_2^2 = 0.055\ v_0^2 \qquad \text{(U)}$$

S), (T) and (U) we deduce for the large meter:

$$(P_1 - P_0) = \frac{0.888\ v_0^2}{2g} = (P_2 - P_0) \qquad \text{(V)}$$

meter:

$$(P_1 - P_0) = \frac{0.945}{2g} v_0^2 = (P_2 - P_0)$$

in both of which last double equations the differences of hydr
head $(P_1 - P_0)$ and $(P_2 - P_0)$ bear constant ratios to the heigh
due to the throat velocity v_0.

Inasmuch, however, that as above pointed out, by the inserti
a Venturi meter in a water main the adjoining up and down st
sections are actually converted into two distinct connected reser
R_1 and R_2, of which that (R_1) on the up-stream side, has the
to perform of stemming pressure in reservoir R_2 on the down st
side, through the limited enclosed passage left for that purpose,
such time as the volume of liquid issuing from R_1 in a given
becomes reduced to rather less than the quantity of water that
ed through the pipe previous to the introduction of the meter i
same time, it is clear that the equalities (V) and (W) can neve
tain, as the up-stream pressure P_1 must invariably be greater
the down-stream pressure, P_2, otherwise motion of translation v
be impossible in the water in the connecting ajutage-pipe.

Again, in accordance with the law expressed in the said the
we should also have:

$$(P_1 - P_2) = \frac{v_1^2}{2g} - \frac{v_2^2}{2g}$$

But considering that as already pointed out, the pipe in wh
meter is inserted is invariably supposed to have practically the
diameter at both ends of that meter, the up-stream velocity v_1
always be equal to the down-stream velocity v_2. For this re
equation (X) becomes: $(P_1 - P_2) = 0$, which result can evid
never be verified.

These failures of Bernouilli's theorem are generally attril
to an abnormally great head, or pressure destroying action of
tion, which is supposed to obtain in the meter; but this explan
is, it seems to the writer, simply a make shift tantamount t
admission that we are rather much in the dark as regards the
cause of the glaring want of concordance of many theoretical
experimental results. For, as above pointed out, it is inconceiv
how such an enormous loss as 70 per cent., or more, of head c
be caused by friction alone during the passage of water throu
straight piece of pipe polished inside, having a length barely e
to 15 times its mean diameter.

The writer presumes that if he were making such remark
the foregoing.—which might be construed to be in derogatio
Bernouilli's theorem—before certain noted hydrodynamic

el like favoring him with the rejoinder, that the case water through the Venturi meter is precisely one of to by them in their treatises, where "the frictions" *s)* cannot be disregarded and that the failures of Ber-em, above indicated, are due to just such an abnormal ie friction generated by the stream flowing through it-divergent ajutage as might reasonably be expected. to such an argument, the writer believes nothing ed to meet it could be said by him than to reiterate in l way what he has already stated herein in this con-that he fails to see how ordinary friction which is the he rolling or sliding of one body over another can be ie formation and propagation of a freely contracted projected through a simple circular orifice in a thin all of a reservoir, nor yet in the transformation of the city factors of the momentum developed in the said of a combination of convergent-divergent tubes such , excepting as regards the frictional resistance which etween the moving liquid and the sides of these tubes. n acquired by the mass of a body moving in vacuo is sed nor diminished by any change that may be effect-pe of the body during its flight, by interior forces sufficiently strong to disrupt it, and it is evident from the case, that in a continuous perfectly liquid vein no ny kind takes place.

a continuous stream or vein of a homogeneous viscous n as syrup, tar, pitch, soap, marl, plaster of Paris, etc., forced by pressure through a simple circular orifice, semi-fluid or fibrous vein becomes contracted on m side of this orifice, much the same as a perfectly result which proves that all these veins are pro-ce according to similar laws if not absolutely accord-the same law. If the flow produced in such semi-fluid ns is slower than that which obtains in similar per-ns formed under the same respective pressures, it is f friction being generated within the semi-fluid or ces in motion, but on account of the infinitely greater e force of cohesion uniting their constituent mole-ared to that existing in a nearly perfect liquid—as to be overcome, before a continuous flow of such be established.

g $(P_1 - P_2)$ the difference between the up-stream and ressures or heads, P_1 and P_2, as the basis of measure-w of water through the entire meter, the height due elocity v_0, becomes: $(P_1 - P_2)\, C_1^2$, where C_1 is a co-

efficient deduced from the experimental data available; t

to $\frac{v_0}{\sqrt{2g(P_1-P_2)}}$ and according to Bernouilli's theorem, t

viz., $(P_1-P_2)C_1^2$ should prove to be equal to the actual

between the pressures or heads, P_1 and P_0, which obtain

stream cross section and at the throat, as determined

gauging, that is to say, we should have: $(P_1-P_2)C_1^2=$

By referring to columns 6 and 7 in Table G, it will eas

that this mathematical equality is not realized, and tha

velocities the difference of pressure or head (P_1-P_0), a

directly with the gauges, is smaller, and for high veloc

greater than the corresponding computed difference of hea

C_1^2 based on the actual effective pressure (P_1-P_2). For

group of experiments No. 1 of Table G, we have for an eff

of $(P_1-P_2)=0.317$ ft.: $\{(P_1-P_0)-(P_1-P_2)C_1^2\}=-0.821$ ft., wh

No. 10, for $(P_1-P_2)=3.544$ ft. we have: $\{(P_1-P_0)-(P_1-P_2)C$

ft., and in group No. 20 of Table G this difference reaches

mum value of + 4.835 ft. for $(P_1-P_2)=11.203$ ft. In the e

recorded in Table H, similar, as a rule smaller, but mor

discrepancies obtain, as appears from the results given i

6 and 7 of this table.

Now, there can be no room for doubt, but that $(P_1-$

represents the difference between the mean positive pre

and P_2, which actually obtain in the maximum up-stream

stream cross sections of the meter respectively, where the

invariably run full; but the case is different as regards

or throat portion of the meter. At this point there must

from the nature of the case, more or less indefiniteness i

file of the free vein issuing from the upper convergent inle

fact the proportions of the conoidal vein projecting b

down-stream side of the small base or tip end, CED, o

vergent upper cone must necessarily vary with the diame

base, the pressure P'_1, the corresponding value of i_v and

of convergence of the sides of the conical inlet, so that

most favorable conditions, it is difficult to arrive at the

of the freely contracted vein in the cylindrical throat, at t

of maximum contraction of the vein, viz., at th

which corresponds to the throat pressure, P_0, ind

the vacuum gauge. Around this contracted secti

must always be a zone of eddy water and vapor, which does

part of the body of the stream, the same as happens in a

indrical tube, added directly to the side of a reservoir, or

connection between two reservoirs, viz., at a point distan

e tube from the reservoir, at the up-stream end of
s appears that the velocity co-efficients C_1, entered
H, correspond sometimes to streams of larger cross
se for which the velocity co-efficients C are com-
s of experiments Nos. 1 to 6 inclusive of Table G,
Nos. 5, 8, and 9 of Table H, and sometimes to
er cross sections, as in groups of experiments Nos.
G, and in experiments Nos. 1, 2, 3, 4, 6, 7 and 10

VII. Conclusion.

ve considerations it is easily seen that the theore-
veen the volume or the velocity of the flow of water
turi meter and the difference between the pressure
am end and that at the throat of this meter, is
simple as assumed by Mr. Herschel and as would
expression:

$$\text{Quantity} = a\sqrt{H}.$$

ker and Mr. Strickland in the introduction of their
enotes the difference ($P_1 - P_0$) between the pressure
am end and the pressure P_0 at the throat of the
a "constant" connecting the flow with the dimen-
r and the head.
: that convergent-divergent ajutages or Venturi
different proportions and shapes, may be inserted
ply pipes and the up-street pressure (P_1) and the
P_0) continue to so adjust themselves *within certain*
at their difference ($P_1 - P_0$) corresponds nearly to
ead $\frac{v^2_{CED}}{2g}$ due to the throat velocity v_{CED}, owing
a part of this velocity is the result of a gradual
f momentum and the balance is due to a bodily
uid particles in parallel lines, both of which con-
the throat velocity vary in contrary directions
ive pressure ($P_1 - P_2$), the ratio of the sec-
ea to the sectional pipe area and the general
forms of the inlets and receivers. It

does not follow, however, that a close coincidence between (I

and $\frac{v^2_{CED}}{2g}$ such as that which obtained in many of Mr. Her

experiments and in a number of the McGill experiments, mu

tinue to subsist for all pressures and all sizes of meters, a

matter what be the ratio of pipe area to throat area and the g

proportions and profiles of the inlets and receivers. Moreove

sidering that in those experiments of Tables G and H whe

throat velocity v_{CED} actually proved to be nearly equal to th

to the difference (P_1--P_0) of the up-stream and throat water c

pressures, the values of co-efficients C_1 fluctuated in the 15 se

such experiments out of the total of 21 series of Table G; b

1.799 and 2.397, and in the 8 corresponding experiments out

10 of Table H between 1.861 and 2.641, it cannot be said—j

by the indications of the experimental determinations—th

Venturi meter invariably permits either the whole or the san

centage of the water carried by the free pipe to pass throu

throat.

The closer we keep with the tubular envelope of the meter

pipe of uniform bore, that is to say, the larger the throat us

the smaller the ratio of pipe section to throat section; (a) the

er will be the pressure utilized to transform momentum, viz.,

called actual loss of pressure (P_1—P_2), after being correct

—viz., diminished by—the loss of pressure due to friction; al

the smaller will be the pressure accumulated at the up-stres

of the meter, in excess of that which obtains at the same p

the clear pipe, and hence the smaller the risk of the origin

charge being reduced by back pressure ; the volume of water

ed to pass through the meter in a given time being greatest

the throat is left of the full bore of the pipe, that is to say, er

up to its greatest possible width or diameter. On the other

when the ratio of the diameter of the pipe to that of the th

the meter becomes infinitely great, viz., when the throat is

completely closed up ; (a) the whole of the throat velocity

duced by the transformation of momentum and the portion c

velocity which, in ordinary cases, is due to bodily translat

liquid particles in parallel lines vanishes, viz., is reduced to

the pressure accumulated at the up-stream end of the meter

cess of that which obtains in the clear pipe is a maximum a

volume of discharge through the meter is reduced to a min

viz., to 0, for the entire original discharge through the free

now stopped and turned back to the source of supply ; (d) th

sure utilized to transform vein-momentum, viz., the so-called

), diminished by the loss of pressure due to fric-
maximum.

here ajutages or meters are used having throats of
s between the extremes just defined, the discharge
at in a given time must consequently be smaller
l discharge through the free pipe which obtains in
d under the same pressure conditions, and a part of
the velocity of this discharge which is accumulated
end has invariably to be utilized to force the water
age, which must necessarily cause a relative depres-
ure at the down-stream end of the latter as well as
essure—altogether independently of any depression
sed by the friction developed along the sides of the
usually only of secondary importance.

fore, to the writer, that the greater part of the loss
volume of discharge which is now experienced with
the Venturi type, could be obviated by giving to the
ceiver such proportions and forms as would cause
ty of momentum to be transformed in the conver-
jutage so as to increase the velocity at the expense
ed, which is required to secure unfailing and well-
ns of the variations in pressure corresponding to
ctuations in the volume of discharge, it is consider-
practicable to register accurately—instead of so
tracting the pipe at the throat of the meter, that
ion of the comparatively large proportion of the
h the free pipe may be effected, which is found to
secure a difference ($P_1 - P_0$) between the up-stream
ures, that is nearly equal to the theoretical head due
t velocity, whether we find ($P_1 - P_2$) or ($P_1 - P_0$) to
antageous variation in pressure to use as argument.

kes the liberty, before concluding his remarks, to
n of the Society to further experiments bearing on
r discussion, which he would like to see under-
r future.

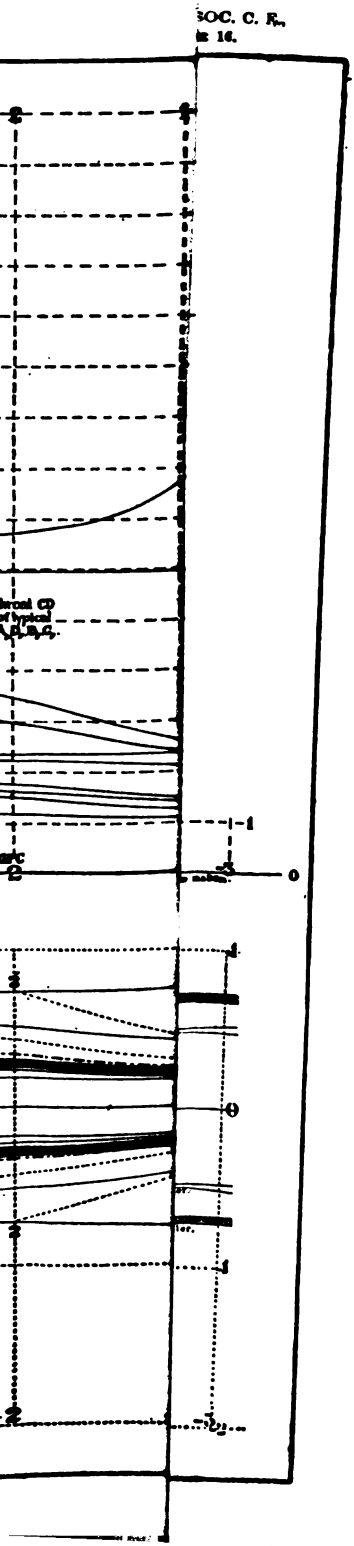
instructive to determine experimentally the actual
ge of the total quantity of water carried by a free
unintercepted by a meter, under fixed conditions of
pass through the identical same pipe under the same
w—when a meter is inserted in it. That is to say,
ould be measured in both cases with the gates of
let valves remaining precisely in the same positions
above the inlet valve being kept at a uniform in-
and down-stream pressures (P_1 and P_2) should also

be observed in each case at the same points of the line of pi
well as the throat pressures.

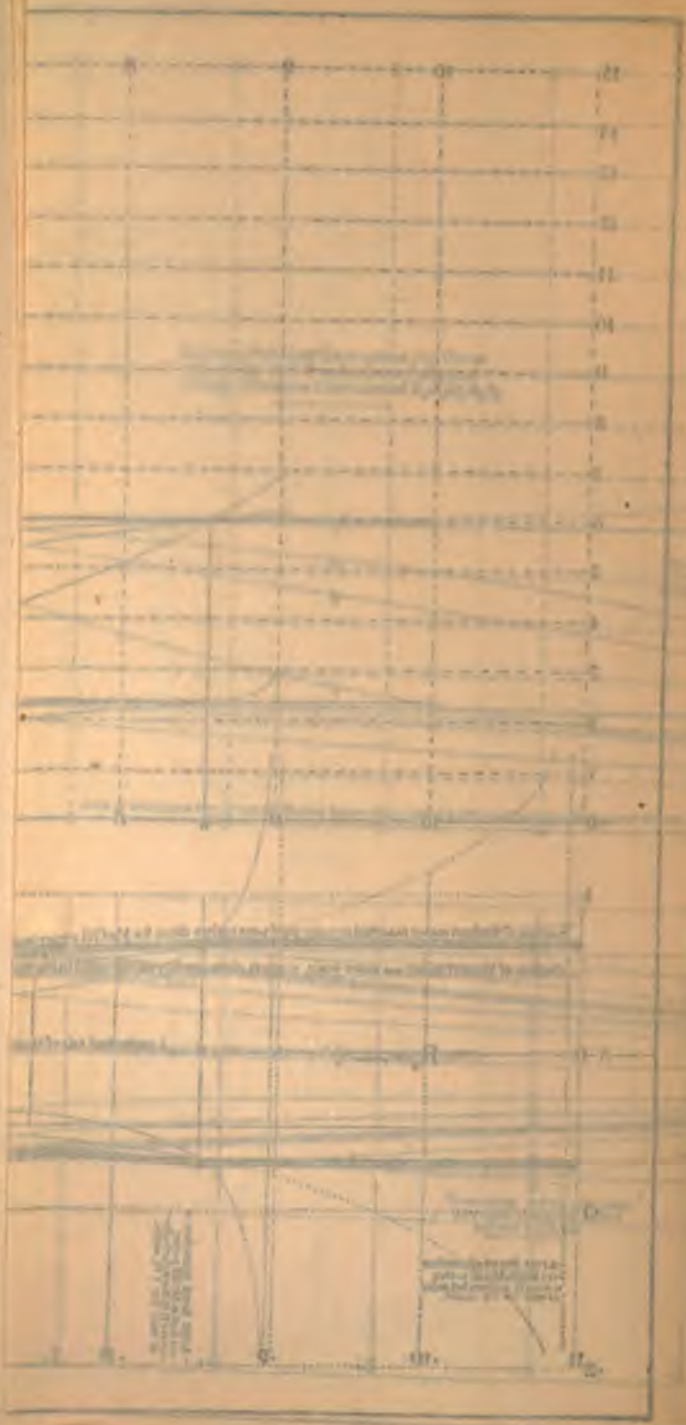
Finally, the writer would like to see further experiments
bearing on the efflux of water under various pressures in a va
through cylindrical and divergent tubes, similar to those ma
Hachette, above referred to, and some with convergent-div
ajutages constructed along the lines herein above indicated an
more rapid streams than have been so far used; additional pr
gauges being also inserted and read, near the lower end of the
gent-receiver or lower cone.

K

Joker



Joker



DISCUSSION.

. Coker thought it would be interesting to some of Prof. Coker
to examine the meter used in the experiments. It
nple thing, consisting essentially of two cones. One
tively large angle at the apex, and the other was a
ergent cone, opening to the down-stream end of the
er cone was not the best form, and the experimenters
re of that when they made the experiments.
refully read through all of Mr. Herschel's work. He
experiment on divergent openings that a cone with
at 5 degrees to the centre line of the pipe gave the
The attempt was to find out if the Venturi meter
ed to small flows,—not to obtain data with regard
m of cone. Therefore, a short divergent cone was
t was convenient to turn its interior surface in the
was difficult to accomplish with a very long one. It
t the Venturi meter could not be very well adapted
tities of water, such as a house supply. It was
venture on a theoretical discussion of the results,
stability of the motion of the water seemed to render
a almost impossible. There was no doubt, however,
experimental results were correct, the facilities for
te experiments having been exceptional.
ot been able to do more than briefly glance
Steckel's paper. There were, however, one or two
shed to touch upon. He would like to know, for
e, whether Mr. Steckel had taken into account the
divergent cone the motion was essentially unstable.
int which could not be lost sight of in any mathe-
ation. With regard to the relation between the
of a jet flowing into the atmosphere through an
k, and the contracted vein of the meter, it seemed
that the two were essentially distinct. The con-
water jet was due to the water flowing to the orifice
parts of the tank. In the case of the Venturi meter
ne in which there seemed no possibility of getting a
such as occurred in a free jet. The water must fit
flowed through the meter.

Mr. Steckel. Mr. R. Steckel said with regard to Prof. Coker's remarks the difficulty of investigating the effect of eddies and other irr motions in the flow through the convergent-divergent adju that the appliances for the work were very imperfect, and had so far never been constructed any such adjutage on c vertical lines.

Mr. Pitcher. Mr. F. H. Pitcher said the Montreal Water & Power Co was about to instal at one of its pumping stations a six-n gallon, high lift, two stage, centrifugal or turbine pump. The was to be driven by a three-phase induction motor at a sp approximately 750 revolutions per minute. It was, of c unnecessary to state before the Society that with such a some accurate means other than the relations between the n of revolutions per minute and the water discharged, must hand to measure the water pumped. For this purpose, the V meter seemed admirably adapted.

It was, therefore, Mr. Pitcher's intention to have ordere this station a Venturi meter having a daily capacity of th million gallons. Should the first centrifugal pump prove to success, a second would be installed, and the meter would th times be worked to its full capacity. The makers of the mete a guarantee, within a certain degree of accuracy, betwee limits of one and thirteen million gallons per day. It wo interesting to test the performance of this new type of pum with electrical instruments and the Venturi meter, a fair i its performance should be obtained. This would be the first of that capacity and type in Canada, and was to be used for r water works service, against a head of 135 lbs. per square pressure.

Mr. Steckel. Mr. Steckel replied, that in the larger capacity meter, s would be installed in the plant mentioned by Mr. Pitcher, much head would be lost, which is now commonly considered all due to friction. In the larger meter, there would be more going through, and at the same time the water which actual go through could be measured by more refined methods.

BUSINESS MEETING.

f the Society for opening of ballots for the election
s held on Thursday, December 15th, 1904, Mr. W.
, Member-of-Council, in the chair.
McLea Walbank, J. Johnson, G. B. Ashcroft, H. R.
amieson, J. W. Heckman, and E. A. Rhys-Roberts
ppointed scrutineers of the ballot, declared the
d:—

MEMBERS.

BOUR. A. N. MOLESWORTH.
AN. J. C. T. CROFTS.
T. E. NAISH.

ASSOCIATE MEMBERS.

RD. F. E. LEACH.
B. KRUMM. E. B. MERRILL.
EY. N. DE C. WALKER.

ED FROM CLASS OF ASSOCIATE MEMBER TO CLASS OF MEMBER.

SON. R. J. DURLEY.
C. H. B. TOPP.

ERED FROM CLASS OF STUDENT TO CLASS OF ASSOCIATE MEMBER.

NNY. F. S. DRUMMOND.
R. T. GOUGH.

STUDENTS.

DELL. H. HADLEY.
FER. S. W. HAMILTON.
SBESTER. JOHN HOGAN.
UNNER. D. L. MCLEAN.
E. R. POTTER.
NES. J. ROBITAILLE.
N. N. J. SLATER.
MIER.

GENERAL SECTION.

Meeting, December 22nd, 1904, Mr. W. McLea Walbank chair.

After some discussion on Mr. Leonard's paper, "The I Heat from Iron Pipes," the following paper was read:—

PAPER No. 213.

BRIDGE LAUNCHING.

By B. J. Forrest, M. Can. Soc. C. E.

The writer's object in presenting this short paper to the of the Society, is to call attention to a method of erection bridges, which, though it has been for many years in vogue i land and the Continent generally, has not hitherto been adopted in Canada.

The construction of a bridge may be simple, but the erec the same is governed entirely by local circumstances, and i tries where lumber for falsework is scarce, and the cost of labour is high, it is necessary to seek such means of handl work in the field as will entail as small an outlay as possi these items.

The particular work to which attention is called, is the e of several steel bridges for the Central Bahia Railway, America. The design for these bridges was prepared by the who also had personal charge of the erection, and the bri lected for description is one of 203 feet length spanning gorge, the base of rail being about 180 feet above water lev the sides of the gorge being very precipitous.

The difficulty of successfully designing the bridge was en by the fact that this portion of the country is liable to severe of earthquake, and suitable provision was made for the supp the trusses, as will be described later.

Owing to the cheapness and facility of procuring ceme stone, the abutments and wing walls were built of concre concrete being braced and tied together with old rails and ti as indicated on drawing, since it was found that the adjace was cracked and fissured for a considerable depth. The lines of cleavage of strata ran north and south, and the direc oscillations east and west.

The method of erection of the bridge was as follows: suspension ropes 1-5 8″ diameter were carried across the

den roller bents at each abutment and connected
nored at each end. Each half span was assembled,
le of the opening, and hauled to the beginning of
e second panel of each from the centre was securely
inged top of a temporary wooden braced boom 80
was pivoted on the rock face of the gorge as shown
the centre panels of the bridge were placed rolled
which rested on the 1-5 8″ suspension ropes. The
s and girders were stiffened by the use of 5-8″ steel
. These were also used for alignment, and in
auling ropes in starting, stopping, balancing and
travel of trusses. The shore ends of the trusses
unched rested on skids, the ends being counter
ch as possible during the launching. These skids
and are shown in the illustration. Powerful screw
when the skids jammed.

s of ¾″ steel were attached to the trusses, the haul-
plished by the aid of a locomotive, and blocks and

ds of the half spans met at the centre of the open-
; up and adjustment was done by means of jacks
ful cam jaw levers bolted to upper and lower chords
holding them in position while the joints were being
hen this was done the centre and end cross girders
es and spandrels of upper and lower chords were
on, and after these the wind bracing, laterals, floor
s.

weight of the truss was carried on the 80 foot boom,
s were assembled at such a height that when the
t together, the lowering of the top end of booms
of wedges would bring the trusses to the necessary
he finished rail level.

cupied in launching and closing up the trusses was
, and for fixing platform, raising, clearing and clos-
t one day. Freight traffic was suspended for three
d approaches raised, and abutments altered to suit
during this time. Passengers and baggage were
s by means of a small, low level trestle bridge,
of bridge material and urgent freight were carried
pension ropes.

l of the existing bridge, which the new one was to
unt of increased rolling loads, was removed by
booms, gear and tackle as were afterwards employed
e new span.

entioned, special end bearings had to be designed
sion for displacement by earthquakes. As will be

seen in plate, the shoes were of disc form, resting on a num
balls, these in turn resting on bed plates of suitable dished
This form of bearing was found to work in a very satisfactor
ner during earthquake shocks, which gave oscillatory mot
centre of span of about three inches, with no signs of cracks
tlements of abutments or wing walls.

The total weight of the bridge as launched, was about on
dred and twenty tons, thus giving a load on each launching
of from thirty to forty tons.

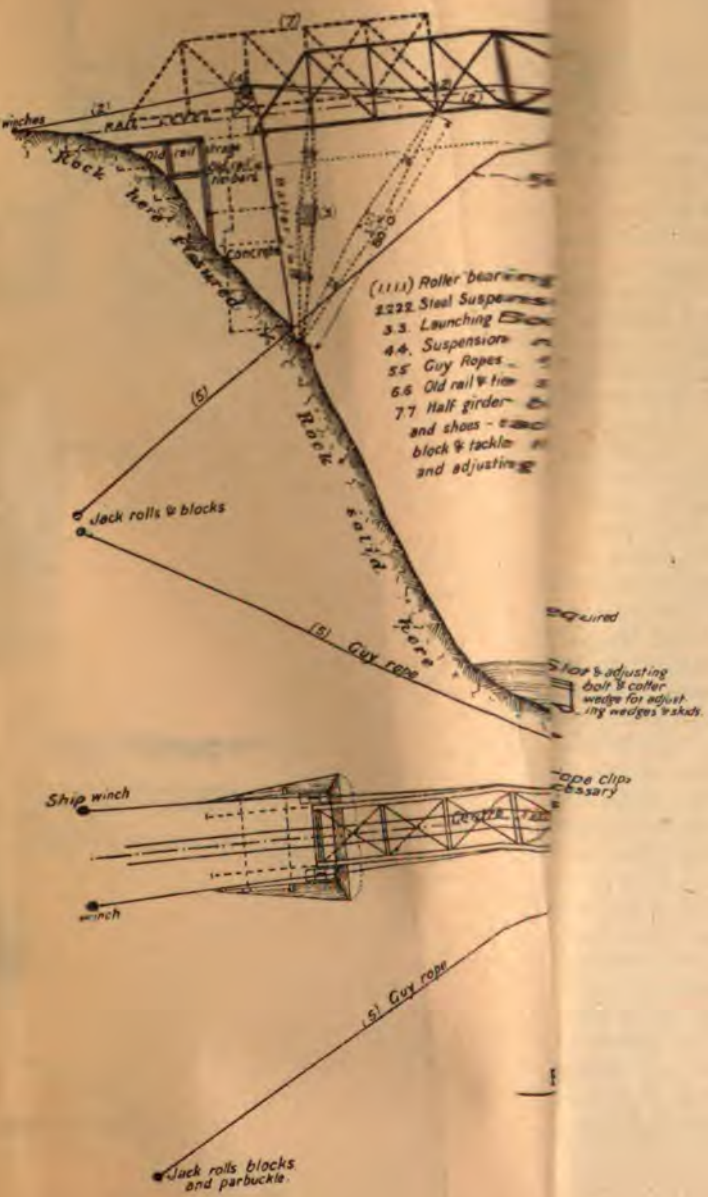
Provision was also made for adjusting the rail approac
the use of four moveable track entrance trussed beams 12"
fixed at each end of bridge, one end being strapped and bo
side of end floor beam, the other end resting on cross beam b
skids and wedges for facilitating alignment and levelling
track entrances into bridge after earthquake shocks or sett
of ground.

The cost of erection and launching, including labour, m
and transportation of same, was about $500.00.

The material used in construction of the bridge was ste
unit stress allowed being about 13,000 pounds per square in
both tension and compression.

Maximum deflection at centre is about 2½ inches.

The main joints of trusses at the centre, as also the gusset
were rivetted, all other connections being bolted, chiefly on a
of lack of skilled labour and with a view to facilitate speed
tion.


winches
Rock here
Old rail
Concrete
(1.1.1.1) Roller bearing
2.2.2.2 Steel Suspe
3.3. Launching
4.4. Suspension
5.5 Guy Ropes
6.6 Old rail & tie
7.7 Half girder
and shoes
block & tackle
and adjusting
Rock solid here
Jack rolls & blocks
(5) Guy rope
Slot & adjusting bolt & cotter wedge for adjusting wedges & skids
Ship winch
winch
(5) Guy rope
Jack rolls blocks and parbuckle.

35

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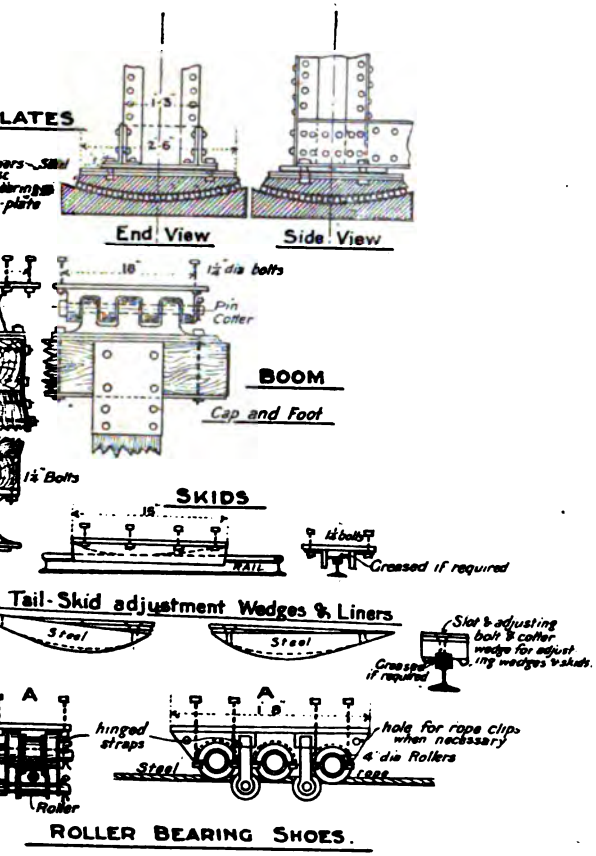


ROLLER BEARING SHOES.

DISCUSSION.

Mr. Shearwood.

Mr. Shearwood asked the following questions:—

(*a*) Although the launching method has often been us Europe and Australia for erecting bridges,—have not some means been employed to support the half spans, and is no rocking boom a novel feature?

(*b*) Why should not the floor beams, cross struts, etc., been placed in position before launching? In this way the two structures would have been rendered more stable to move, an assembling of these members would have been simplified.

(*c*) Were there not some means provided for holding bac half spans when nearing the closing point? The angle whic booms make with the vertical being about 30 deg., and most c weight being carried on the booms, an anchorage of about 15 appears to have been required at each corner.

(*d*) The booms being placed beyond the centre of gravi the weight launched, no load would be carried by the suspe cables, and these appear to have been superfluous as far as la ing the span was concerned.

(*e*) The form of adjustable rocker bearing as shown i illustration would soon be filled with water,—was there any vision to keep dirt and moisture from filling in between the and so rusting their surfaces as to prevent free movement?

(*f*) No provision appears to have been made for expansio contraction, and the bed plates have no anchor bolts shown to them in place. Were these plates simply laid on the concrete, no definite connection?

(*g*) In view of the frictionless nature of the ball-bearing face, is there not a danger of the bridge being blown out base plates? The horizontal force would only have to be enough to alter the direction of the resultant reactions abo deg. from the vertical to unseat the span.

Mr. Forrest.

Mr. Forrest answered as follows:—

(*a*) He was not aware of rocking booms having been em in bridge launching of this kind.

(*b*) Floor beams were very heavy and deep, only three fixed in position in each half span, and three cross struts an in panels (one at each end and one in middle), all with the of stiffening span without adding much to its launching weig

(*c*) Half spans were bolted to head of rocking booms, were held under control by powerful sets of double purchase b and tackle, and wire ropes attached to a locomotive (one on

ents), which easily controlled travel of spans. All Mr. Forrest.
oyed were double purchase and securely anchored to

uspension cables were used principally for assisting
g alignment, and assisting in steadying spans and
y materials.
pper rocker bearings had several oil feed holes and
the lower bearings were filled with thick native
signs of water could be seen in them.
bearings were securely bolted to flanges of lower
el sleeve bolts and washers, working in oval holes in
ed plates—lower bed plates were similarly attached
corresponding cavity, and bolted and washered in
nents.
; two heavy gales much less oscillation was observed
ins passed over at high speed, as bridge was at bot-
ades and entrance of two curves (one on each side);
than during earthquake shocks; the greatest oscilla-
as in centre of lower portion of span during these

ark said he could not help noticing the sum of Mr. Goldmark.
bor,—which worked out to about $4.00 per ton for
work. He did not think American engineers would
work in the same way. It looked like a particularly
a steel arch or cantilever.

nk also thought that the figure was rather low Mr. Walbank.
cost. The author had called attention to the fact
oor was scarce there, which was probably the reason
n question was adopted. He also wished to know
er those conditions would be affected by earthquakes
it would in this country?
wood thought that an arch with three hinges would Mr. Shearwood.
as any simple truss or cantilever span.
possibly the engineer had feared settlement in the

t remarked that the author had spoken of oscillation Mr. Ellacott.

sent the following answers to the questions raised Mr. Forrest.

d to cost of erection, native labour was very cheap.
ployed were as follows:—One foreman (Scotch-
merican negroes (sailors) as riggers, and about 20
ropes, spars and tackle were procured cheap from a
The erection of false work would have been very

Mr. Forrest. He had proposed a cantilever or arched span as eas erect, but the company had a cheap offer of suitable materia as skilled labor was scarce, it was decided to make use of it.

In answer to Mr. Walbank, he thought not, under the conditions.

In view of trouble experienced with other bridges c line, he had been afraid of some settlement in abutments, were cross-braced with old rail-bolts and washers on that ac

The general direction of cleavage of rock (if it co called so) would be nearly north and south, the general dir or line of shock oscillations would be nearly east and west.

Mr. Jennings. Mr. W. T. Jennings sent in the following questions o paper:—

1. What was the design of the original structure?
2. What was the material composing it?
3. When and how was it erected?
4. Could it not have been used as false work for the erect the new span?
5. The weight of metal in the new span should be given the stated cost for erection, etc., can be reduced to a short to for comparison with other methods.
6. Does the cost of erection, as stated, cover the laying needle beams, or deck and guard rails?

Mr. Forrest. Mr. Forrest sent the following answers:—

1. Through composite (wood and iron) triangular truss.
2. Wood and iron, badly worn, rusted and decayed, and demned by Government Inspector. Only a small shunting and a few cars were allowed over at a time.
3. Erected about 1870, in sections on false work. It was costly and long operation.
4. It was too narrow, awkwardly situated and badly in the and not trustworthy, being badly worn and condemned.
5. New bridge, 1,120 tons; old bridge about 85 tons; wei track and ties extra (about 15 tons).
6. Partly, as they were used in removal of old bridge pr launching new one. The deck and guard rails of the old were used again.

MINING SECTION.

President—J. B. Porter.
Vice-President—K. W. Blackwell.

meeting of the section was held on Thursday, Decem-
, Dr. J. B. Porter in the chair. The following papers

4.

LUES AND FLUE DUST AT ANACONDA.

By C. H. McDougall, S. Can. Soc. C. E.

lem of recovering the solid matter from the gases
ne various furnaces, is one that during the past years
much attention at Anaconda. This is more especially
e the erection of the new smelter in 1902. Since then
the arsenic liberated in the smelting process became
nt.

me of construction it was thought that the height of
which the plant was placed together with steel stacks
the reverberatories, roasters, blast furnaces and con-
d lift the smoke to such an elevation as to prevent it
jury in the adjacent valley. However, on commencing
was found that the prevailing winds more than
iced the benefits thus obtained, and the deposition of
atter on the neighbouring farm lands gave rise to
on.

ly this, as well as to save the solid matter, which con-
percentage of copper, the plan used at the old works,
ing a brick flue from the furnaces to the top of one of
ing hills and there erecting a stack, was adopted and
on. The result is, that at present a flue giving the
ng area, and a stack with the greatest capacity yet
giving the most satisfactory results, and the old
the arsenic has been completely overcome.

the accompanying sketches shows the arrangement of
parts of the plant and the flues carrying the gases to
The lengths given for the different parts are horizontal
s and do not denote the true distances the gases flow
ng the stack, on account of the slope on which the flues

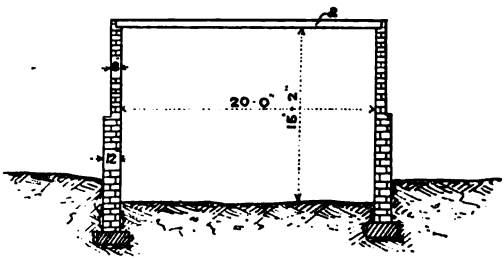
Blast Furnace Flue.

cing at the blast furnaces and following the gases as
-they are conveyed from the upper part of each fur-

nace (a) Fig. 3, to the dust chamber (b) by means of a flu
shown in section. Seven of these flues enter the dust
ber, one from each furnace, and they are all provided with h
as shown at d_1, d_2 and d_3, to allow for the draining off of a
dust that may accumulate. These hoppers are opened once
week, and the dust found is returned to the furnaces.

The dust chamber itself is 38 feet wide and 275 feet lon
walls are brick with steel framing, and the roof at the p
time is constructed of steel rails placed 9 inch centres, with
between as shown in the construction of the roaster flue (F
Cement and expanded metal have been tried with poor resul
former being acted on by the sulphuric acid in the gases to su
extent, that in a short time the roof became unsafe. In all
the latter method of construction has been replaced with
bricks and mortar.

Fig. 4.



Section of
Blast Furnace Flue

The chamber proper is built about 9 feet from the ground
admitting of a means of drawing off the flue-dust into car
hoppers g_1, g_2, g_3 and g_4, are arranged in four rows lengthw
the chamber; the roof and floor are supported by four ro
6-inch columns equally spaced across the chamber and placed
centres for the length of the structure. (See Fig. 2.) For
there was a partition at right angles to the flow and extendi
full length of the dust chamber—save for the openings at the
thus compelling the gases to traverse a considerable distanc
fore entering the flue. On examination it was found that pr
ally all the dust was deposited on the side next the inlet,
the time of the construction of the flues this partition wa
moved, and the gases now pass directly to the flues, (t).

Flue dust accumulates at the rate of from 60 to 70 tons
hours, and is the coarsest material thus obtained, pieces of
and limestone being abundant. Assays show it to be lower in
per and arsenic values than that from the other chambers.
dust drawn off is sent to the reverberatories.

commences at the north-east corner of the chamber otal length of 1,653 feet to its point of juncture with atory and roaster flues. This extreme length is due to in construction of passing around the end of the ore

FIG 5

udinal Section of
f Blast - 60' Flue

FIG. 8

Longitudinal Section
Roaster Converter and
Reverb Flues.

first half the sides are exposed, but in the latter part e is uncovered. A cross section is shown in Fig. 4, the ick, 8 inches in thickness at the top and 12 inches at the inside height is 15 ft. 2 inches and the width 20

is constructed of 5-inch I beams placed 40-inch cen- 5, between these corrugated iron roofing, (b) is fitted of an arch 4 inches length at the centre. The ends of on the lower flanges of the I beams, and on top of the bricks are laid as shown at (e).

de area is 303 sq. ft. Blind doors are built in the s, as in the other flues, every hundred feet, for of removing any flue dust that may become an obstruc-

FIG. 7

Section of
Converter Flue

far these doors have not been used, and at present e or no dust in the flue; this was ascertained last openings were made in the roofs of all the flues at in- feet, three at each section for the blast, reverberatory two for the converter, five for the 60-foot and ten for The depth of dust was found at each opening by means

of a greased iron rod, and a sample taken out with a long h
scoop. The average for the blast flue was two inches, a
greatest was at the bends where the dust had drifted. A
samples were of coarse material, coke and limestone being
dant, as in the dust-chamber. The estimated total quanti
773 tons with an assay as follows.—

Arsenious oxide..	1.6%	
Copper..	7.4%	
Silver..	6.8	oz. per ton.
Gold..	0.035	" " "

The velocity of the gases = 2,542 feet per minute, a
volume 771,060 cubic feet per minute.

Drafts and temperatures are given on sheet A. Inconsis
in the temperatures are not uncommon, and are due to the
number of charging doors open and to the changing condit
the furnace. Plots, as in the accompanying sheet, have bee
showing the relation of draft and temperature in the flue
number of charging doors open.

As a means of regulating the current in the flue, two d
⅜- inch boiler plate, each half the width of the flue, are hu
frame at (h) Fig. 2. These can be lowered at will to cut do
cross sectional area, but at present are kept well drawn ou

Converter Flue.

Although the amount of solid matter escaping from th
verters is large, only a small part of it is carried into the
large part being caught in the boxes placed at (a) Fig. 6
these is is shovelled into cars through the door (b) and re
into the converters.

From each of the nine boxes (one to each converte
flues as at (c) lead to the dust chamber (d) (size 364′ x 38′
latter is constructed on the same plan as the one before de
and the dust that collects here is drawn off at the rate of 1
to 50 tons per day and sent to the reverberatories.

The flue Fig. 7, is the smallest of those described, bei
8 feet wide by 8 feet high. For the greater part of its len
roof alone is exposed, this is constructed of steel rails placed
centres with bricks between, a sectional view is shown in 1

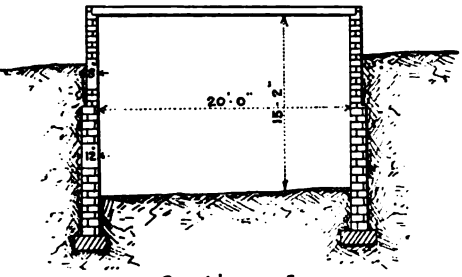
The drafts and temperatures are extremely variable, a
relation of the former to the number of converters blo
shown on the accompanying sheet; the readings plotted were
in the flue just beyond the dust chamber, and show a ra
temperature of 263° F. The inconsistency shown at the tim
22, is due to the fact that the two converters blowing had n
time to warm up after receiving a fresh charge. The temp

ter flame does not materially increase for about ten the blowing begins, but from that till the time of radually rises. The length of the flue to its point of that from the roasters is 703 feet, and at no place on ld enough dust be found to admit of taking a sample. s are hung at the top of the down-take from the as in the case of the Blast Furnace.

Roaster Flue.

ing at Anaconda is done in 48 McDougall Furnaces, vans design, placed four abreast in a building 98 feet the top of each row of four extends a steel flue (a),

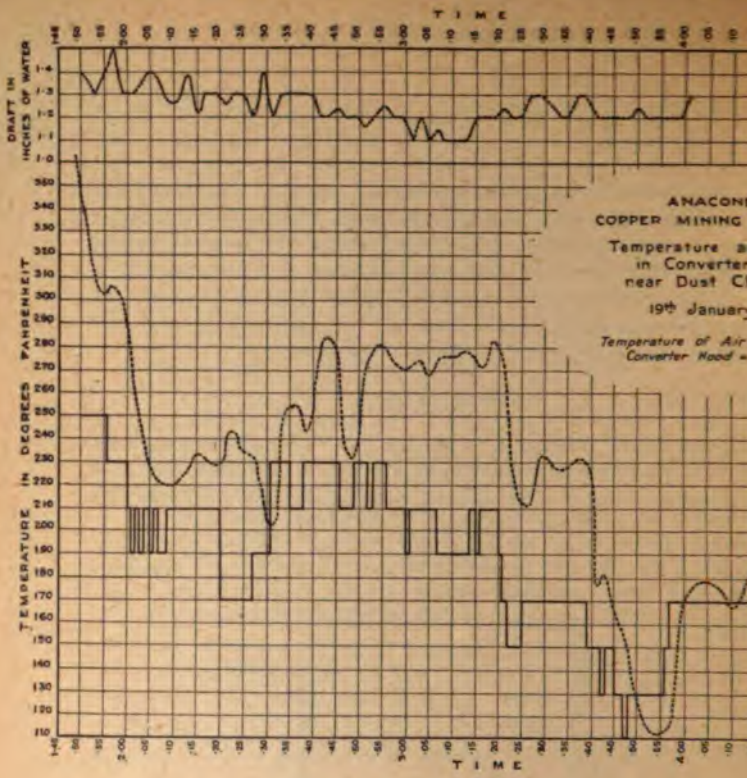
FIG. 10

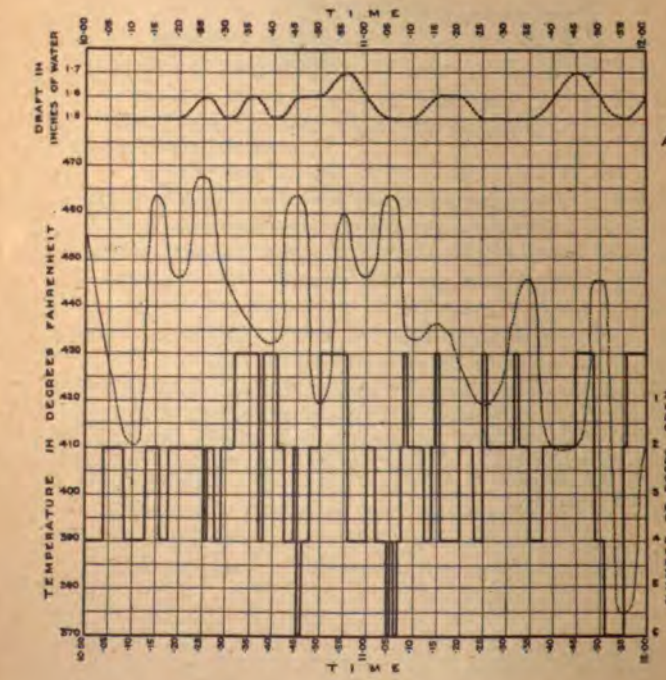


Section of Roaster Flue.

ected by two pipes as at (b) and (c), to each of the (d) and (e) hoppers are placed; the ones marked (d) st that collects into the discharging hoppers of the the ones at (e) into the dust chamber (f). The latter ng and 38 feet wide, and is constructed like the one flue. The amount of material taken out per day and riquetting plant is between 40 and 50 tons.

ter flue has the same cross sectional area as the g. 10), and differs from the latter only in the construc- oof, this being the same as that described under con- he latter joins the roaster flue at a distance of 60 dust chamber.


TIME
DRAFT IN INCHES OF WATER
TEMPERATURE IN DEGREES FAHRENHEIT
ANACONI
COPPER MINING
Temperature a
in Converter
near Dust Cl
19th January
Temperature of Air
Converter Hood
TIME


TIME
DRAFT IN INCHES OF WATER
TEMPERATURE IN DEGREES FAHRENHEIT
NUMBER OF DOORS OPEN
ANACONDA
Temp
in Bl
nea
Approx
Two
TIME

Atmosph.	Furnaces	Stations 1	2	3	4	Furnaces	Stations 1	2	3	Furnaces	Stations 1	2	3	Stations 1 E	1 W	2 E	2 W	Stations 1	2	3	4	5	6	7	8
72° F.	9	329°	310°	300	269	44	165°	164°	146°	6	237°	249°	233°	184°	181°	179°	183°	185°	176°	169°	163°	180°	173°	168°	163°
		2.15"	2.05"	1.95"	2.2"		2.1"	2.1"	2.5°		1.8"	1.9"	2.2"	1.6"	1.7"	1.4"	1.45"	1.4"	0.8"	0.65"	0.2"	1.15"	0.7"	0.3"	0.9"
35° F.	9	308°	297°	287°	260°	44	167°	165°	166°	7	263°	250°	210°	186°	184°	179°	172°	178°	166°	—	152°	177°	172°	—	161°
		2.2"	2.0"	2.05"	2.1"		2.1"	2.2"	2.5"		1.7"	1.9"	2.2"	1.7"	1.75"	1.65"	1.6"	1.4"	0.9"	—	0.2"	1.25"	0.7"	—	0.8"
55° F.	9	*248°	242°	237°	225°	44	165°	162°	153°	7	290°	290°	253°	185°	169°	177°	174°	168°	168°	—	147°	167°	159°	—	152°
		1.9"	1.75"	1.65"	1.9"		1.8"	1.95"	2.0"		1.6"	1.6"	2.1"	1.45"	1.5"	1.4"	1.5"	1.05"	0.9"	—	0.2"	0.9"	0.7"	—	0.6"

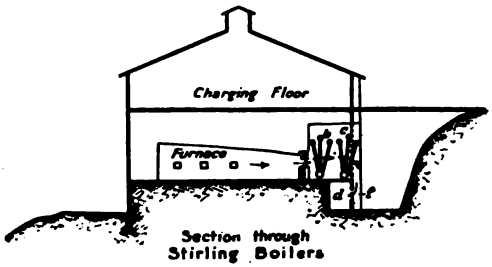
N.B. { Drafts in inches of water.
Temps. in degrees Centigrade.

* Two furnaces were under repairs at the time these were taken, and cold air was being admitted. Hence low temperatures.

The stations given about correspond to those marked on Fig. 1.

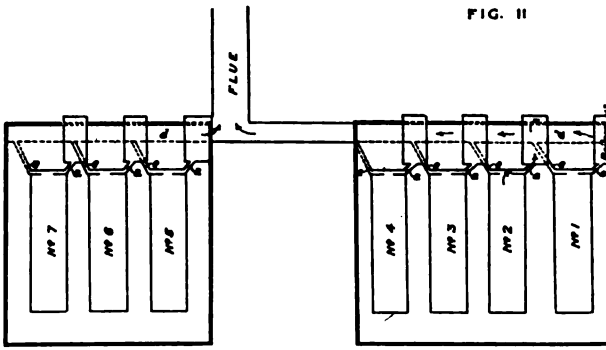
Owing to the fineness of the feed and the nature of th
ment a great deal of material escapes from the furnaces
depths found in the flue varied from 6 inches to 4 feet,
total quantity was estimated as being 590 tons, the assay in
and arsenic being higher than that given for the dust fr
blast flue. For drafts and temperatures see sheet A. Th
length of the flue is 488 feet, the velocity of the gases 3,582
min.,, and the volume in cu. ft. per min. = 943,208. The qu
include the gases from the converter flue.

REVERBERATORY FLUE.



This differs from the ones previously described in ha
dust chamber at the beginning, the gases passing from
ferent furnaces arranged as in Fig. 11 by the passages marke

FIG. 11



PLAN
OF
FLUE CONNECTIONS FOR REVER

the stirling boilers at (b) and (c), and from the boilers
(d). This plan of using the heated gases for the purpose
rating steam has proved a decided success; one furnace gi
enough heat to generate 800 H.P. (700 H.P. in b and 100 in

; are not coated to any great extent by the solid matter cleaning of tubes is not a serious drawback to this tilizing the waste heat. During this operation the gases rectly into the flue through the downtake (e). The nperature of the gases when they leave the boilers is ; is at least 300° C lower than that of the gases when into the flue.

erberatory flue is the same in cross sectional area and ı as the roaster (Fig. 10), and at the time of examina- ained no flue dust. The velocity of the gases was 2,483 nute, and the volume 753,170 cu. ft. per minute. Drafts atures are on sheet A.

Sixty Foot Flue.

commencement of this part of the flue the reverberatory, roaster flues meet and merge into one, called the lue from its inside width. This differs from the ones described in that, besides acting as a passage for the o, on account of a greater cross sectional area, lessens and thus gives the solid matter a chance to settle. For the flue is built with a hopper shaped bottom, Fig. 12; flue is a tunnel (a) for the purpose of removing the

lls are brick, 20 feet high, and vary in thickness from 18 ne top to 24 inches at the bottom. The roof is built in ray as that of the blast flue, but on account of its supported by two rows of 15 inch I beams (b) resting columns C; the latter are 20 feet from the sides and 20 lengthwise of the flue. The area or the cross section is et, and the total length 1,233 feet. The sides of the hop- are bed-rock sloped to 30°, this gives a depth of 37 flue over the tunnel. Baffle walls (d) 8 feet length at are built every 20 feet to aid in catching the dust. The ½ feet wide by 7 feet high, and has brick side walls and brick roof. At intervals of about 12 feet spouts (f) are the purpose of draining off the flue dust into cars, the closed tops and an inlet only through a bag or nozzle fitted over the spouts. This method of loading prevents om escaping into the tunnel.

eration of the cars is described under the one hundred foot flue. At the north end of the sixty foot flue is the he arsenic plant (a), Fig. 1. This is shown in section in ne cars are dropped down to the turn-table, disconnected to the hoist, through the passage (e), the hoist is oper- motor in the motor room and conveys the cars to the

floor (g). There the dust from the sixty foot flue is stored (h) preparatory to being drawn off and taken to the briq plant. The dust from the one hundred and seventy foot flue direct from (g) to bins, and then to the charging floor arsenic plant. There it is roasted in Bruckner Furnaces tha municate with condensing chambers, waste gases passing t into the sixty foot flue.

Varying depths of from six inches to six feet of du found in the flue, the average assay being 8% arsenious ox 10% copper.

Velocity of gases in the flue is about 1,300 feet per minu the volume 211,268 cu. ft. per minute.

Cold air is admitted into the flue through openings as and (e) Fig. 1, as a means of regulating the temperature.

One Hundred and Twenty Foot Flue.

In this part the area of the flue last described is d and it is really a flue formed by building two sixt flues side by side; the outside walls are of the same thickne the partition between the east and west side is built as descr Fig. 14. In the construction of the roof, however, there i cided difference. To permit of greater heat radiation, inst bricks the covering is 1-8 inch steel plate, riveted to 7" I spaced 40-inch centres. These are supported by 15-inch I which as in the sixty foot flue rest on 12-inch I beam co The tunnel and baffle walls are constructed as before des The length of the flue measured horizontally is 995 feet, but to the difference in elevation of the ends (350 feet) the length is about 1,050 feet. The velocity of the gases is abou half that given for the sixty foot flue, and the drafts an peratures are on sheet A.

The flue dust here is nearly all deposited in the part ne furnaces, and as the stack is approached the depth decrease on the last few sections enough could not be obtained to i sample. Usually the copper assay is lower and the arseniou slightly higher than for the sixty foot flue.

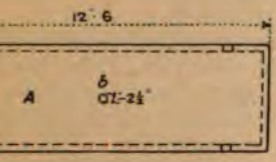
The two tunnels shown in Fig. 14 merge into one just the contraction of the flue to sixty feet. The cars are worl cables attached to drums in the hoist house just south of the Fig. 1 a. The cables are wound on the drums in opposite tions, so that when the shaft revolves one car goes down a other up. The power is supplied by a small electric moto gravity does most of the work. The hoist is run either ei sixteen hours per day, with an average removal of five cars per hour.

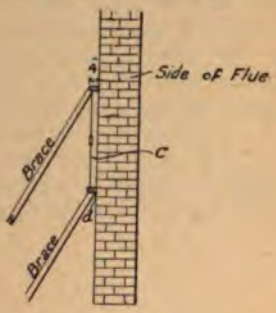
At the south end of the flue is the three hundred foot st

r foot square base. Details of the construction can be
e Engineering and Mining Journal, September, 1903. To
that no solid matter is escaping, every month samples
ke are taken by means of a line of pipe and a fan send-
oke through a tightly woven asbestos bog.

FLUE LEAKS.

ruary, 1904, it became apparent that a large volume of
as leaking into the flue through the sides and roof; to
the amount the following test was carried out:—





S FOR TESTING FLUE LEAKS.

en frame A 12½ ft. long and 4 ft. wide was covered with
ed canvas, a hole 2½ inches in diameter, surrounded
n ring, being left at (b) for the purpose of holding an
. This frame was set up at intervals on the walls and
he different flues, as shown at (c). Air being
om getting inside in any other way than through (b) by
he edge of the frame to the wall as at (e). When set up
en that all the air that would leak into the flue through
uare feet covered must pass through the anemometer,
eing wedged and puttied into the hole (b). Readings
for five minutes' periods until the velocity of the flow
ined. From this result the amount of air passing into
sq. ft. at each set-up was determined. One hundred
fferent places were tried, and from the results thus ob-
the area of the exposed walls, the total amount of cold
in was estimated.

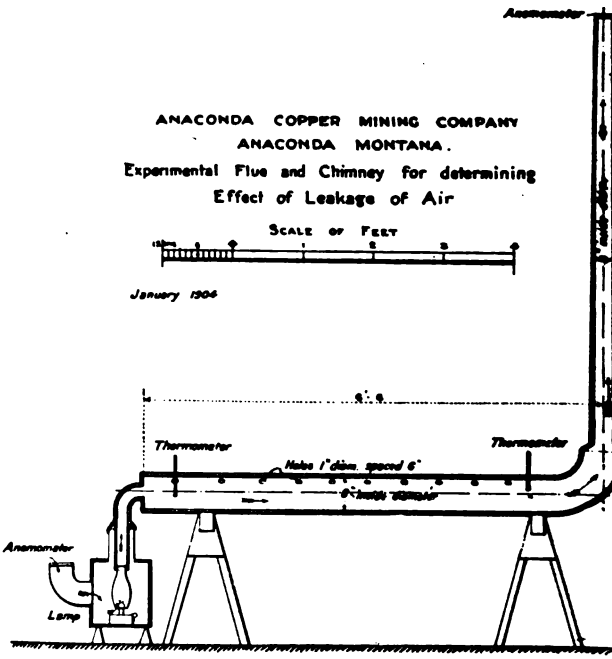
this test had been undertaken an experiment on flue
een carried on as described in the accompanying sheets.
esults so obtained, it was seen that too much air was
to the flues. So to remedy this the whole of the exposed
given a coat of cement, with the result that when again
s found that the leaks had been reduced ninety-five per
at the furnaces was in this way materially increased.

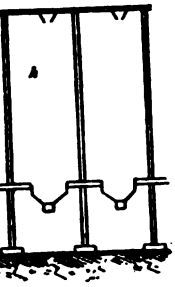
To remedy the rise in temperature in the flues resulting f
exclusion of cold air, openings were made in the sides of
foot flue, and at the present time sufficient cold air is
these places to keep the temperature of the one hundred an
foot flue down to the required point.

Flue Velocities.

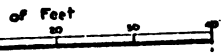
The matter of obtaining correct flue velocities was one
some time offered considerable difficulty, as an anemomet
not be used on account of the temperature and dust. Fin
checking the pilot tube against the displacement of the bl
reliability was established. Since then an exhaustive set
on the different flues have been carried out, and the res
tained have been very satisfactory. The ones given in t
going are from the first set obtained.

In this sketch of the flue system at Anaconda, I have
tempted to give any figures for costs since these can be
from the Engineering and Mining Journal, September, 190
with the methods used in constructing the flues and stack.





60 FT FLUE
T ARSENIC PLANT.



F LEAKS ON CHIMNEY AND FURNACE DRAFT.

e the effect of leaks in a flue upon the quantity gas passing through the furnace, and also up the erimental plant was made of iron pipe, as shown sketch. A number of 1-inch and of ¼-inch holes the flue. A kerosene lamp with Argand burner nace; and was so enclosed that all of the air passd to go through a 2½-inch Biram anemometer, as gas discharged from the top of the chimney. The the lamp, the area of the intake and the discharge himney were the same for all tests. The results

	Velocity in Feet Per Minute.		Temperatures.			
	Intake.	Discharge.	Near Lamp.	Base of Chimney.	Top of Chimney.	External Air.
e closed	140		311°F	172°F	97°F	72oF
		154	318°	179°	99°	72o
e leaks			319°	124°	89°	
area..	92	194	321°	122°	88°	
e leaks	86		303°	120°	88°	
area..		207	300°	114°	88°	
e leaks	83		275°	110°	84°	69o
area..		194	283°	108°	85°	69o

s show that, up to a certain point, when openings flue, the velocity in the chimney increases, but beit decreases again. Every opening in the flue, ses the quantity of air passing through the furnace. t explanation is, that with a tight flue the open- furnace are too restricted to pass the quantity of e temperature conditions are capable with a free a certain amount of leak the temperature condiifficient to carry more air than can pass through he excess is taken in at the leaks. A point is however, where the temperature in the chimney is the quantity of gas previously passed, and beyond ow decreases.

with all the holes in the flue closed, show that was a slight leak, amounting (when corrected for approximately 4%.

atures given above were observed at about two top of the iron flue. At the bottom the temperto 20° less.

DISCUSSION.

Mr. Cirkel.

Mr. Cirkel said that if he understood the paper correc large part of the flue was about 1,200 feet in length. He to ask if the tunnel was constructed under the flue for th distance.

Dr. Porter.

Dr. J. B. Porter remarked that Mr. MacDougall had d in an admirably clear manner a tremendous piece of work, had treated it in such a matter of course way that some audience might scarcely realize the scale upon which it h done. The paper had said that the chief function of the tu to collect dust, and it would be interesting to know how m was saved in this way, and what values it carried in differe of the flue. Apparently it averaged about 10% of copper, doubt a small amount of precious metal. If so, the yea must amount to a very great tonnage and an enormous s values.

The author had not said anything about the effect of A flue gases upon vegetation. Dr. Porter remembered the pri which a lady in Anaconda had once exhibited a few feeble and flowers which she had succeeded in growing in the cou of her home. Nothing in those days would grow at all unl tected very carefully, and the immediate neighborhood smelters was converted by the sulphuric acid smoke into a desert. The effect extended to a considerable extent in certai tions, being affected by the prevailing winds, and garde farms were not only menaced, but destroyed. One of the for constructing the new flue was that it would improve conditions in this respect. The speaker had not been in An since the completion of the flue, but remembered seeing son about a model garden which the management of the smelt recently established.

Mr. MacDougall.

Mr. MacDougall replied that the tunnel was constructed the last 2,000 feet of the flue,—that is, under the 60 x 120′ fl their whole length. In regard to vegetation, the flue had the very best results, and complaints had almost ceased to c from the farmers. The usual effects of smelter smoke we somewhat apparent, but trouble from arsenic had altogether although this element had heretofore been most troublesome model garden had been built almost at the foot of the stac had proved thoroughly satisfactory.

THE CENTRE STAR MINE.

By L. Heber Cole, S. Can. Soc. C. E.

I.—Situation and Surroundings.

Star Mine at Rossland, B.C., is located on the slopes in to the north-west of the city. It is bounded on e Le Roi Mineral Claim, on the north-west by the Iron Mask Claims, the north-east by the Idaho, and st by the Nickel Plate Claim.

claim, 1,500 ft. long by 600 ft. wide, and was located

II.—Geology.

this mine consists of iron and copper sulphides alcopyrite and pyrite, accompanied by arsenopyrite). value is in gold, which is chiefly carried by the ut the copper makes an important addition, and a small amount of silver present.

the country or wall rock, I take the liberty to quote on "The Ore Deposits of Rossland," by Mr. E. B.

e area of the claims the prevailing rock is evidently same magma, but shows innumerable variations in g and degree of metamorphism. It is mainly com- oclase feldspars and pyroxene, generally in about ions, but towards the gabbro area, bodies of pure occasionally encountered. There is usually a small orthoclase feldspar and sometimes hornblende, and rs have noted the fact that these appear more fre- ds the west. The rock appears to be holocrystal- e or less porphyritic. The crystals may be either r as large as, say five mm., while one or two mm. limit. The feldspars are more or less altered to a celain-like appearance, while the pyroxenes are par- rmed to fibrous minerals of the uralite group. In ed places, and especially within the veins, the rock coloured brown from microscopic crystals of second-

varying considerably in different places, specimens have generally been determined by microscopical

observers as augite porphyry, and it certainly belongs
"gabbro group, differing from the central area mainly in
"time and rate of cooling. Broadly speaking, the size of
"tends to increase towards this area, and coarse crystalline
"are more frequently encountered, while in the other directi
"structure becomes more fine grained."

"This country rock is cut by innumerable dikes, which
"detailed comparison and determination by the microscope.
"erally speaking, they appear to be mica traps (perhaps kersa
"and altered basalts (perhaps melaphyre). The latter are
"greatly decomposed."

The veins vary in width from a few inches to 40 or 50 fe
the pay chutes in some cases extend from wall to wall, w
others, only parts of the veins are enriched. Sometimes th
are very indistinct and the valves run into the country and
ally decrease without any sharp line of division between o
country.

The mine consists of several veins, either extensions
bordering claims or else ones starting in the claim itself.
Main Centre Star vein, however, and the one in which most
work is done, is the large Shear Zone Fissure consisting of
lel platings of the rock produced by shearing under high co
sion. This vein runs along the southern slope of Red Mo
and appears in the Le Roi Mine. This vein has a dip
from 60 to 70, and a strike that is approximately N. 68
varies greatly in width, and is cut by a large number of dik
faults.

III.—Surface Plant.

As the Centre Star and War Eagle Mines are under th
management, the offices are placed so as to be convenient t
The office building, besides containing rooms for the genera
work, has draughting rooms, blue print room, photographi
room, surveyor's instrument room, and the private offices
General Manager and Superintendent. The assay office i
veniently near the main office.

The collar of the main shaft is located 500 feet from th
end line and 225 feet from the north side line of the claim.
this shaft, is erected the shaft house. The hoisting engin
contained in a room in the hanging wall side of this building
the part back of the shaft is occupied with ore bins.

The machinery for the machine and timber framing sh
driven by a 100 H.P. Cross Compound Automatic Cut O
Engine. The line shaft is fitted with friction clutches s
each shop can be operated independently. The equipment
machine shop consists of one 28-inch swing and one 16-inch
rican Tool Company's lathes; one 26 by 36 inch American Too

; one 36-inch Barnes upright drill, and one post radial
are also two pipe machines with the capacity to cut
inch pipe, and a bolt cutter to cut from ¼ to 2-inch
whole is served with a three ton travelling crane.
ird of the shop is devoted to the repairing of rock
are brought up from the mine in skips and placed on
travelling crane operated by compressed air. They
from the collar of the shaft to the machine shop and
by the overhead travelling hoist. The machine shop
steam, water, compressed air and electricity for test-
ring. Beyond the machine shop is the blacksmith
he sharpening of the machine drill steel is accom-
drill sharpener. There are three men operating this
besides these, two blacksmiths and their helpers are
l on general construction and repair work for both
drill steel for both the War Eagle and Centre Star
pened by the one machine.

the shaft house and connected with it by two tram-
a 40 by 70 foot mill devoted exclusively to the fram-
imbers, having the latest appliances for framing
nd shaft timbers by power. This timber framing
s built by the Denver Engineering Works. A 48-
cross-cut and a rip saw complete the equipment,
mple facilities for supplying the mine with correctly
s in the least time and most economical manner.

Eagle and Centre Star hoists and Centre Star com-
l supplied with steam from the Centre Star boiler-
contains four horizontal tubular boilers, 5 ft. by 15
acity each, carrying a steam pressure of 100 pounds,
nch by 16 ft. Scotch marine high pressure boilers,
am pressure of 130 pounds and having a capacity of
The fuel used for firing is Crow's Nest Pass coal.
d air is supplied to the mine by a Canadian Rand
's cross compound condensing two stage air com-
drill capacity. When running at its maximum speed
ns per minute, it requires 625 H.P. and delivers 3,960
ee air per minute. The steam cylinders are 22-inch
40-inch by 48-inch, and the air cylinders are 22-inch
l 30-inch by 48-inch. The circulating water for the
oled for re-use after leaving the condenser, by means
wer, located 100 ft. away. This tower is 25 ft. high
g. The circulating water is forced to the top by
-inch by 18-inch single acting Worthington Triplex
elted direct from the main shaft of the compressor.
vs in thin layers over the shutter-like veins of the
so doing, it presents a very large superficial area to

the direct contact of the air. This air in passing freely the tower takes up much of the heat of the water and t it. From the cooling tower, the water returns by gra settling tank, from which it is again handled through the ser and around the same cycle by means of the pump. denser is of the Wheeler Admiralty surface type. All Ce and War Eagle compressors discharge into a common s that any compressor can be used in the running of either

IV.—Development Work.

1. *Prospecting*:—Prospecting and development were s the usual manner on the Centre Star Claim. The ve exposed by surface stripping in several places, and pr shafts were sunk on the veins. Two tunnels were run i on the level that is now the second, and from these tunn pecting proceeded by means of cross-cuts, drifts, winzes a When it was considered that the mine was sufficiently pr main shaft was sunk. Work on this shaft proceeded at ferent points simultaneously, viz., sinking from the surf ing from the second level and sinking from the second le mine is now worked entirely through this main shaft. T is sunk from the surface on a level which is called the account of there being other workings above it. The coll shaft is 3,688 feet above sea level. The shaft has a dip o its direction is N.38° 49′ W. There are three compartment which are used for skips, while the third is used for a and for the pipes for ventilation and compressed air. E partment is five feet square, inside measurement. From t eight levels are being worked, varying from 125′ to 175′ the slope.

At each level, a large station is blasted out so as to le to handle the ore into the skips. Just below each station pocket to hold ore is cut. These are made, so that by a gate at the bottom, the ore is allowed to shoot straight skips by gravity. From the station, cross-cuts and dri been run in different directions to locate and work the or

2. *Drifting*:—Where possible, the drifts are driven a foot wall. Since the rock is extremely hard, there is no ing required in the drifts.

The average advance per round of holes is 4.5 ft., wor machine for two shifts per day. The total advance for varies from 70 ft. to 100 ft. The grade of the drift is ⅞ cent., and the drainage runs at the ends of the track tie ing is always kept well in advance of the ore extraction expose new parts of vein for stoping.

Raising:—The raises are put in at irregular distanc

e are usually two compartments, one a man-way
chute.
he back in raises, a temporary platform of sprags
ank, which is pulled down before every blast, is
en to stand on.
rill Work:—Two sizes of drills are used, one with
utside and 1⅜" core diameter, and the other with
" core diameter. The machines are seldom used
three hundred feet deep. They are firmly fas-
s. Compressed air is used to run them.
e drill, especially for those drifts in which tram-
on, a short cross-cut is first blasted out to give
chine to be operated in without interfering with
. The rods are square threaded and are in 5 ft.
re pulled in 5 ft. to 10 ft. lengths according to
ehind the drill. These rods are hollow to allow
orced through them to the bit, but are of smaller
than the core barrel to which the bit is attached.
th of the core pieces saved, is from 5 inches to
n the full length of the core barrel is kept intact

ines are screw fed and fitted for 300, 700 and 1,000
nch of advance. Their ordinary speed is 300 R.
ximum of 1,500 R.P.M. The water is pumped
rods by a small independent force pump run by
In an eight hour shift, the average progress made

of the core are broken up and assayed, after a
on by the Superintendent.
k in which the drilling is carried on, is very hard,
ired to be reset frequently. Each bit will only
before resetting is necessary. By skillful setting,
for a new bit is generally avoided.
stones in large bits, with the average value of
he bit has a flat cutting surface, into which the
k. Two smaller ones are often set on the outer
keep the rod from sticking. To set the diamonds,
d into the end of bit perpendicular the cutting
he inside and the other four on the outside. These
n with chisels so as to fit the diamond roughly
em. Then the metal (sometimes a piece of cop-
gradually hammered into position so as to enclose
firmly.
ole is not deep, the rods are pulled by hand, but
ft., the work is too severe, especially in putting
rum is then used, on which is coiled a wire rope.
e rods can be handled with great facility.

The core, after it has been examined and sampled, is
trays and put on shelves in the core-house for future r
Every core drilled in the mine is kept.

V.—Ore Extraction.

1. *Stoping*:—

Narrow Stopes:—A large part of the working consists
row stopes under 15 ft. wide. Having carried up the rais
cient height, stoping begins at the lowest limits of the pay
the stope is driven to the boundary of the pay chute.
stulls are put in and a close floor of lagging is spike
stulls. Stoping above the floor then commences.

The broken ore is kept up close to the face so as t
footing for the machine men to work from. The ore that
slide by gravity into the chute is taken by wheelbarrows o
led into wooden troughs that lead to the chute.

When the pay ore begins just above the drift, a rais
kept in advance of the stoping, since the whole back is w
a stope. In this case, there is a permanent tight floor le
the drift.

Wide Stopes:—For stopes of a width of from 15 ft.
square sets take the place of stulls. The length and br
the ore body is first determined and the sill floor is co
Breaking down the ore from the back is then started. So
in wide stopes it is necessary to use a tripod for moun
machine drill, but wherever possible, drill bars or drift
are used. These are set vertically between the back, and
porary scaffold or pile of broken rock as a base, and back
is continued. Enough space is always excavated above
floor, put in to leave room for drilling the back. For a c
width in the ore body, the stope is extended by attach
hanging or foot wall, or by leaving out as many sets as
sary, according as the vein widens or narrows.

2. *Drilling*:—

Drills used:—Most of the drills are 3¼ inch diamete
stroke, Rand Drills of the Little Giant Type. These are
sion drills and are operated by compressed air. They ar
where possible on the drifting columns, which can be brace
sides of the drift or to the floor and the back. Where th
this is impossible, a drill tripod is used which is supplied
drill.

The drilling steel is diagonal in shape, and is welded
shank of steel. These shanks vary in length from 18 incl
ft. One shift of eight hours will dull about 30 bits for each

holes for drifting:—A round in this mine generally
n holes arranged as follows:—
les.
oles.
s.

k is heavy, a couple more holes may be added, one
d one more back hole. The length of the holes varies
ft.
:—These are inclined at an angle of about 30° to the
the back or roof, so as to keep the back at the
above the floor.
es.—The next row of holes, called breast holes, is
ghtly off the horizontal, just enough to hold water.
reak down the portion immediately below that part
back holes are placed, so as to relieve these upper

—Below the breast holes is another row, placed so
n at about an angle of 45°. These are the cut holes.
the central portion of the drift so as to allow the
act.
he two bottom holes are drilled in at an incline
as to form a wedge shape with the cut holes. They
he floor on a level. These are barely water holes.
oles in each row are inclined either to the left or to
rding to which side they are on, in order to keep
n even distance apart. Where the drift is required
to left or right, all the holes are inclined in that
rding to the amount required to turn.
holes in raises or winzes:—These holes are so placed
centre cut holes are blasted, it leaves a free area for
s to break into. Eighteen holes is the general num-
und, three in each line.
similar round is used for sinking, with the except-
entre holes are more inclined to each other to give
power. The average length of hole is from 6 ft. to
t sinking, a great many more holes are used, as the
ken is generally larger.
Stoping:—The holes for stoping are so placed that
eaking power of the charge can be utilized. The
ed horizontally in rows, one above the other.
:—When possible, all blasting is done at night. The
a.m. to 7 a.m. are set apart for this. Two men then
g for the whole mine. By this means, the mine is
and smoke for the morning shift.
used:—The dynamite used is manufactured by the

Hamilton Powder Company. The sticks are in sizes of 1
and ⅞ inch. The former are of 40% and 50% strength, wh
⅞″ is of 60%. The different grades are used as follows:—

In stopes..	40%
Drifts..	40% and 50%
Shafts and raises..	50% and 40%

Use 50% for cut holes, if ground is breaking hard.

The 60% powder is only used to break boulders, and wh
hand drill steel is used to drill holes, as in case of timberin

The average charge for a drift round of 10 to 12 holes
90 to 100 sticks, about 45 pounds.

The cartridges are put into place and are rammed i
holes by a long wooden pole. They are then tamped wit
muck. A long fuse is attached to the outside cartridge i
hole. These fuses are so timed, that the shortest will bu
minutes, thus giving the men time to get into safety.

In drifts, the cut holes are fired first. Then the breas
and lifters, and last of all the back holes are fired. This
complished by shortening of the fuses of the cut holes. In
etc., the centre holes are first fired, then the following r
order.

Stope holes (horizontal) are fired one row at a time. T
then charge the next row above and fire that. They contin
until the whole round is blasted. Similarly in shaft sinki
centre holes are blasted and the muck is cleaned out bef
next row is fired.

Where men are on contract, the round is blasted when
is ready. The blasting is then done by the contract men
selves.

4. *Mucking*:—When the working place is clear of smo
mucking of the ore begins. The muck is loosened by pi
shovelled into small cars, which are then trammed to th
station by men. No horses or means of mechanical labo
used underground, with the exception of on the second leve

Here a small stationary hoisting engine is used an
out eight cars at a time. It is impossible for this to be d
men, since there is a heavy grade along the drift on acc
the drainage being towards the mouth of the tunnel. At t
tions, the ore is emptied into pockets beneath the station
directly into the skips. The car is dumped by hand, the b
the car alone dumping, leaving the truck on the track. A l
the back opens the front end of the car. It can be emptied
direction from the rails on account of the turn-table movem
tween the truck and the body of the car.

The rails are 16 lbs. per yard. These are spiked to ties

2½ ft. apart. The laying of the tracks is kept well
e work in the faces of the drifts. The curving of all
e underground as required.

r used stands 2 ft. 11½ inches from top to rails, and is
designed for the company. It holds 16 cubic feet (ap-
).

ting:—The main hoist in the mine was supplied by
ebster, Camp & Lane, of Akron, Ohio. It has two
h 6 ft. by 3 ft., with a capacity of 1,700 ft. of round
of ⅞" diameter. The average winding speed is 800′ per
h a maximum of 1,000′ per minute.

gines are 14-inch by 18-inch stroke with a Stevenson
Gear. A Lane Friction Clutch is attached, thus per-
either drum being used independently, so that hoisting
rried on at the same time from different levels. The
is prevented from cutting the footwall shaft timbers by
ed on the wall plates at long intervals.

ip employed runs on a 30 lb. per yard steel rail spiked
wall plates of the shaft. The shaft guides are chiefly
purposes, so that the safety clutches can grip them in
dent.

Veight of skip..	2,400
oad of ore..	4,000
Total weight w thout rope..	6,400

ps are fitted with Humble Detaching Hooks, so that in
an overwind, the rope is instantly detached, hanging
in the head frame.

ety clutches attached to the skip are so arranged, that
becoming slack (as in breakage) they are at once re-
couple of powerful springs. By digging into the guide
bring the skip to a dead stop. They have already been
o use in the mine and were found to work very effi-

winze is being sunk, a small temporary hoist is
sed and the muck, etc., is hoisted in a bucket running
It is dumped automatically into cars when it reaches

when hoisted from the mine, is dumped into bins,
it is drawn and trammed to the shipping bins inside
ailway.

ring:—On account of the solidness of the rock, tim-
ot required in the ordinary drifts and cross-cuts. In
raises, stulls and lagging are used most extensively, but
ope becomes too wide (15 ft. is about the limit) square
opted. Square timbers are also used in the shaft.

The timber is supplied to the mine in the following for

Square timbers:—10″ x 10″ square by 16 ft. long. Fir best wood for these, but spruce and pine are sometimes used

Planks:—3-inch and 4-inch x 16 ft.

Stulls:—These are logs varying in diameter from 10″ with the bark removed and cut into lengths of about 16 ft.

Lagging:—This is small round timber left in the rough a 16 ft. lengths. Tamarac is what is generally used.

Adjacent to the framing-shop and connected with it by t is a commodious timber yard. The timber is hauled by along the road on the upper side of the yard. From the wa it is rolled down skids and piled. When required, it is br into the framing shop on trucks. The swing-saw is used fo ting the timbers to the required lengths, and the square ti are framed by the timber-framing machine. From the fr shop, the timbers are trammed to the collar of the sh needed. For lowering the timber into the mine the ordinary are generally replaced by a special platform timber skip.

In the shaft, the sets run at right angles to the dip, the square set stopes, the floors are always laid level. O other hand, in the narrower stopes where stulls are used, the placed approximately at right angles to the walls. The end in hitches moiled or chipped out of the walls, and only in cases is powder used to cut these hitches.

The timbers are finally firmly wedged into place by w wedges. On top of these is placed the lagging, so as to fo solid floor. The flooring used in the square sets is 3-inch a inch planking.

7. *Pumping*:—The water encountered is comparatively sm amount and is non-corrosive. Three pumps, one on the 4th another on the 8th level, and the third in the sump of the are sufficient to cope with all the water.

A large new pump to be run by electricity, is now bein stalled at the 6th level station. When in place, this pump w the pumping for the whole mine.

The drifts and cross-cuts are drained, by having them all to the stations of the shaft, except No. 2 tunnel off the 2nd which slopes away from the shaft to its mouth.

8. *Ventilation*:—The mine is provided with a No. 4 Blower with a 14″ delivery. It runs about 8 hours per da supplies 150,000 cubic feet of air per hour. It is driven by H.P. induction motor. The blower is reversible and can th used either to force fresh air into the mine or to exhaust the air. The escape of compressed air from the working drills, assists the ventilation.

The air is blown down a main, set in the ladder-way o main shaft. This main is made of round galvanized steel a

oldered with large joints. Branches of small pipes at each level where necessary and carried along the o the stopes.

more or less natural ventilation either up or down e to its connections with the tunnels. When stopes end from level to level, a certain amount of ventila- secured, but when these are not completed, artificial required. Much time is saved by this means of ven- the smoke and the large quantities of poisonous d by the explosion of the powder, are very quickly y the reversed blower and the working place cleared can be resumed very soon after blasting.

y:—The main shaft, stations and principal tunnels are electric incandescent 32 C.P. lamps. The wiring for ting is carried down the shaft in an iron conduit action boxes at each station. The wiring is so ar- t can also be used for flash signals if needed.

ones:—There is telephonic communication between all mine buildings, and also between the lower mine the shaft house. The system is private, and is so no central exchange is needed. The directions for follows:—

rough using telephone, place plug in left hand soc- ou may be connected from any other phone. In call- , insert the plug in the number required and ring. nswering ring and then take down receiver and pro- ess."

s:—Electric gongs are used for station signals, but used to move the skips. Batteries are placed on seventh levels; they last about three months with- Sampson cells are used.

VI.—Surveying and Mapping.

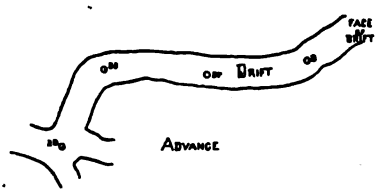
ork:—Except where very accurate work is required, of all mine buildings is done by the stadia method. ork is to be done, a transit and band tape are em- the levelling, an ordinary level is used. All eleva- ulated from the B.M. located on the Bank of Mont- in Rossland.

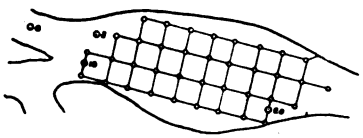
nd work:—In all underground work, only accurate done. The transit (reading to minutes) and steel entirely. Survey stations are set at convenient in- e mine. These stations are accurately located from the shaft. The methods then employed are as fol- ns are placed in the back of the drift, etc., by drill- ut 4" deep by 2" diameter. Into each of these holes ed a wooden plug, which is driven level with the

back. Horseshoe nails with pierced heads are placed in the
so as to allow of plumb bobs being hung from them. A bras
with the number of the station on it, is fastened beside each

Survey of advance:—the advance is surveyed twice a m
It is taken up as follows:—(See diagram) Transit set up at St
37. Vernier set at 0° B.S. on Station 33. A sight is then take
Station 81 and angle read. Angles are always read twic
doubling, as a check. The elevation of Station 81 is then lo
by means of a button set on plumb bob at 81 on a horizonta
from the transit.

The horizontal distance between 37 and 81 is measur
nearest hundredth of a foot and contours taken left and
from line. This operation is repeated at 81, and sight is tak
face of drift.





LOCATION OF SQUARE SETS

SURVEYING - CENTRE STAR MINE.
ROSSLAND B.C.

Location of square sets:—Transit set up at Station 5.
diagram). Vernier at 0° B. Sight taken at Station 6, and
angle, turned in a clock-like direction to Station 19, is meas
Elevation of transit below Station 5 is measured. Vertical c
set at 0° and button set on line on plumb bob at Station 19. I
zontal distance between Stations 5 and 19 measured. Trans
then set up at Station 19 and angle turned to Station 20,
Station 5 as a back-sight. Station 20 is placed in the cap o
square set, the same distance from the post as Station 19. I
ing of line 19-20 is then the bearing of square sets.

Stopes not having square sets are surveyed in exactly
same way as the drifts, except that a longer contour rod is
Where the walls are very irregular, sights are taken on diff

e transit, and angle turned is read and the distance
The transit telescope is never plunged.

of bearing of D.D. holes:—A sub-station is located on
he drill rod in the same way as a station is. Transit
p over sub and sight taken to collar of hole with the
as B.S. The line from sub to collar is the bearing.
ey of stopes for the vertical projection is, in the case
opes, taken up with the transit. Transit is set up in
ocated from the nearest station) so that the back can
and sights taken to points on the back and vertical
nd distance measured.

et stopes are taken up with a 14 ft. rod and steel tape,
an always be reached from last floor.

rk:—The bearings of all lines taken underground are
from the azimuth of the back sight. The co-ordinates
ns only are worked out by the traverse tables. All
are plotted from their bearing and distances.

king maps on which all underground work is plotted,
convenient scales. In the general plan, all stations
rom N. and E. co-ordinate lines. The vertical section
a plane parallel to the dip of the shaft.

l maps are kept of each level, also assay sheets on
otted all assays run. Tracings of all maps are made
ting.

VII.—Assaying and Sampling.

:—When ore is loaded on cars, it is sold direct to the
that all sampling of shipments is made at the smelter
l.

ples are taken from the face and all headings after
xcept where running through known country, and
casional samples are taken.

—The samples to be assayed consist principally of
cores, daily mine chip samples and smelter controls.
ck is kept by assaying a floor sample, as well as the
trol on each shipment lot. This floor sample is ob-
lows:—When the last cut is made on the sampling
melter sampling mill, half is sent to the smelter assay
e other half, which is called the floor sample at the
directly to the mine and is treated there exactly as
he smelter office. The smelter sample is ground and
gh a 120 mesh and divided into three parts. One part
the smelter, another part is the control that goes to
the third is kept for umpire. What remains on the
form of scales, is cupelled separately and the result
pulp assay as metallics. The mine control has had

these metallics extracted from it, and in order to keep a on the metallics, the above mentioned floor sample is taken

The control samples are assayed for gold, silver and c The six fusions of one-half assay ton each, are run for gol the average taken. The flux used is a litharge flux as follo

Litharge..	70 grms.
Soda Bi-Carbonate..	15 grms.

and enough nitre or argol to give a 20 grms. button. In or determine the quantity of nitre or argol to add, it is necess run a preliminary assay.

The smelter uses a nitre and nails flux, but the mine that by using a different flux, it can obtain closer results wi smelter.

The iodide method is used for control coppers, and f others the cyanide method is employed.

VIII.—Water System.

A very complete water system is now in operation, whic plies both the Centre Star and War Eagle Mines with wat boilers and compressors, and also for fire protection. water is obtained from the Centre Star Gulch and is handled No. 5 and a No. 6 high duty Cameron pump and a Snow D pump. The water is raised 500 ft. through a three inch pipe, feet long and discharged into a 30,000 gallon tank beside the Eagle shaft-house. One hundred feet below this, there is an 30,000 gallon tank. On the slope of the hill above the Centre shaft-house, there is a third tank of the same capacity. It is vided with a 1,000 gallon per minute Snow Duplex Underw Fire Pump, which is always ready for immediate use, using steam or air. This pump will give a pressure of 150 lbs. An sides this, there is at the level of the company's offices, a na pressure of 100 lbs. at the hydrants. The system has 28 hyd placed at convenient points to protect all the buildings of mines.

Every employee of the company is put through a fire drill there is a regular fire department in connection with the apart from the city brigade.

IX.—Working Hours and Wages.

Two shifts only of eight hours each are worked. The n ing shift goes at 7 a.m. and works, with an hour's intermis till 4 p m. The second or afternoon shift starts at 4 p.m. with an hour for supper at 6 p.m., works till 1 a.m. Two men ing the hours from 1 to 7 a.m., blast all the ground drilled ready for breaking and turn on the blowers, thus leaving the free from smoke and ready for the morning shift.

le of wages is as follows:—

aft men.. .. ..$	4.00
achine men..	3.50
mbermen..	3.50
uckers..	2.50
rpenters..	3.50
achinists..	4.00
acksmiths..	4.00
" Helpers..	3.00
oisting engineers.. .. ..$3.00 and	4.00
wder and tool boys..	2.50
rface labourers..	2.50

face men work ten hour shifts with the exception of rs, who only work nine hours, and hoisting engineers, ight hours.

tract system is used largely in both the development the stoping, and is found to be very satisfactory. are paid for the amount of advance made in the form- engths of holes drilled in stoping. By this means, hat the drills are used to better advantage during tne hifts.

e is shipping steadily every day large quantities of to the Trail Smelter, and also during this last sum- t of milling ore has commenced to the company's new .

DISCUSSION.

Mr. Cirkel. Mr. Cirkel remarked that it had been pointed out that in this mine was exceedingly hard, and he wished to ask were any information available with regard to the rate of He had noticed from the photographs that some of the ho drilled almost horizontally, others vertically. He would know how deep the diamond drill holes usually wo how many feet could be drilled per day. He had had some ence in the Rossland district with ordinary rock drills, not sure that they could do more than 25 feet per shift, would be interested to know what was being done at the Star in that direction.

Mr. Smith. Mr. J. Burley Smith asked the dip of the vein. In the graphs of the timbering, he had noticed that nearly all of were vertical,—yet he thought he had understood the autho that the sets were at right angles to the dip. He would know why there were no diagonals in the square set timber said that judging from the lantern slide, the timbering weak, and that in his opinion much greater strength cou been secured by making the timbers perpendicular and pa the dip.

Mr. Cole. Replying to the first question regarding diamond drill Cole stated that the drilling ranged from 8 to 12 feet p While he was at the mine there were three shifts per day, the drilling usually amounted to about 24 feet. With ai only two shifts were worked per day, and it usually too shifts, or about a day and a half, to drill and blast one r ten holes, with an average depth of five feet. In other wo actual drilling was at the rate of about 25 feet per sl remainder of the time being spent in blasting and muckin

In regard to the timbering, the paper stated that the the shaft were put in at right angles to the dip of the shaf was approximately that of the vein. In the narrower sto sets were at right angles to the dip of the vein, but in t stopes, regular square set timbering was used in floors whi laid on the level, so that all timbers were horizontal or The dip was about 70 degrees.

Dr. Porter Dr. J. B. Porter said he could confirm Mr. Cole's figur diamond drilling. Two or three years ago he had been giv accurate information in regard to diamond drilling in t Eagle. There the drilling averaged almost exactly one f hour.

g to Mr. Smith, Dr. Porter said that he believed the
ll was so strong that no great strength of timbering
ry, and that the square sets were used largely for con-
handling the ore. It was quite true that the timbering
been much stronger if placed perpendicular to the
it it was strong enough as it was, and, of course, far
nient. If, however, the pressure had been greater, it
been necessary either to change the direction of the
to use diagonals.

Burley Smith asked for the dimensions of timber used, Mr. Smith.
cost of timbering per ton of ore.

e stated that the large posts and caps were 10" square, Mr. Cole
ne of the timber was smaller. Much of the timber was
than once, being removed from a stope when the latter
nd set up in another place.

kel said that he understood that the shaft sinking was Mr. Cirkel
of 70 degrees, and that work was done at three places
id the author mean that at the second level, they both
sank? He also wished to know whether they left a
een the two sets of workers. He considered it very
o sink a shaft under men who were raising, unless this

le replied that he was not sure whether a pillar had Mr. Cole.
the Centre Star sinking, but at the War Eagle a floor
mbering had been used.

ter, in closing, stated that the usual practice in the Dr. Porter.
sinking a shaft in which work was going on overhead
the rock pillar or pentice referred to by Mr. Cirkel, and
in British Columbia and the western part of the United
a very strong feeling against the use of timber protec-
r as Rossland was concerned, he believed that the War
the only mine in which the timber pentice or bulkhead
sed for this purpose. In other parts of the world, how-
ustom was quite common, and there was no reason to
e safety of a timber bulkhead if it were properly built
ntly cushioned with timber and filling.

eference to Mr. Smith's question as to the cost of tim-
Porter said that Mr. Cole was in the position of a great
ents. Young men are often given access to mines, and
given every possible facility to work and to secure
in regard to mining, but they are naturally expected
ing about costs. In many cases, students had their own
the economy, or otherwise, of the methods they were
to see, but under the circumstances a discussion of the
always a delicate matter, and in some instances permis-
it the mines was only given on the condition that costs
be given out.

Dr. Porter Further, he thought that Mr. Smith's criticisms of th vagance of timbering were applicable to many mines Rossland district. It seemed to him that British Colum copied too closely the practice of the Butte district. In th place, very heavy square set timbering was used very fre as the majority of the miners in Rossland had come fron they had perhaps unconsciously got into the habit of using timbering than the Rossland conditions necessitated. I camps this tendency had been corrected, and it was to be ho tonnage costs for timbering would soon be reduced, not Rossland, but in many other places in the West.

s.

RANSCONTINENTAL TRANSPORTATION.

By G. H. Blanchet, S. Can. Soc. C. E.

s at present considering the problem of transportation interest than has been shown since the time of the of the Canadian Pacific Railway. This condition, as dvance in the development of the country, should be nal satisfaction, but also one deserving national con- r the future of Western Canada will be largely in- he outcome. It should, therefore, be met by a broad, icy, in order to develop the country, both inland and he best advantage, and minimize the cost of transpor-

essential is system. We need a great national sys- and subsidiary lines embracing the whole of the pro- ry and affording as cheap and direct routes from the tres to the seaboard as the geographical and physi- of the country will permit. Each railway entering hould be considered and laid out as a unit of such rder that each should have sufficient tributary country commercial success.

has been recognized as long as the question of trans- ransportation has been in existence. Sir Sandford f engineer of the Canadian Pacific Railway during on, impressed upon the Government the advantages be derived from a great national system owned by t it was unwilling to assume the responsibility, and onstructing the first transcontinental railway fell e company.

dian Pacific Railway could not be laid out on any t was built in answer to an urgent appeal from the had, therefore, as far as possible to be located so as ttled districts which were in general in the South. by design, partly of necessity, the Canadian Pacific built through the South of the fertile belt.

ruction of the Canadian Pacific Railway wrought a ange in Canada. It linked the several disjointed individual and mutual benefit. The centre was d developed and provided with an outlet, and the ted by increase in material for manufacture and twenty years have now passed since the completion

of this road, and the wonderful development, in which it w of the chief factors, scarcely needs to be dwelt upon. Th has been changed from a hunting ground to a national and national wheat field and stock farm, and the commercial tance of Canada has been increased from little more than an tation of necessities till it has become a factor in the ma the world.

Settlement at first naturally kept near the railway, but expanded beyond this, following the fertile river valleys. time to time branch lines were sent off to include the settle but even with these the railway accommodation is insuffic meet the increasing demand, and traffic is each year be more and more congested, till the appeal for additional me transportation has aroused interest all over the country.

The commercial possibilities which this condition of tra tation offers have not been overlooked by private companie during the last few years several schemes have been form providing additional outlet for the produce of the West. It these that public interest is now centred.

It is generally considered that there must be another line to connect the producing centres of the prairies to th water in the East. The two salient ideas are: that it clusively on Canadian territory, and that it should affo cheapest possible route to the East for the produce of the

The subject may be considered under four heads:—

(1) The possibilities of our waterways.
(2) A railway owned and operated by the Governm
(3) A Government owned railway leased to a privat pany.
(4) A railway built by a private company, subsidi otherwise aided by the Government.

We have now the main elements of the problem, let u sider in detail the various schemes offered for its solution.

(1) The Possibilities of our Waterways.

It is the opinion of many that grain will always seek a route in preference to railway and, therefore, with the wat facilities offered by the great lakes, St. Lawrence and C River, it would be folly to build the difficult and expensive p of the route eastward of Port Arthur. Undoubtedly the route has many advantages, but it is seriously handicapped count of the season of navigation being so limited.

The Government has appointed a transportation comm to investigate fully the possibilities of the various water-r This commission is headed by Sir Wm. Van Horn and co men of experience in both shipping business and practical

should be of value in showing the condition and pos-
our waterways.

(2) A Government Owned Railway.

e many arguments for and against railroads owned
by the Government. Many point to the Intercolonial
the impossibility of a Government railway being
commercial success, but this contention is invalid
ercolonial was not planned to pay. It was built for
ons, which though making it a national benefit violated
ntials of railway construction by taking the longest
ite between the terminus. No such handicap need
overnment extension to the Pacific. Moreover, if the
does not pay in actual revenue, it does in commercial
the public by keeping rates low. This latter consid-
e of tremendous importance in connection with an
ailway accommodation for the North West wheat, for
t of the West is largely controlled by the profit de-
roduce, and this is influenced to a large extent by the
portation. The age of low rates resulting from rail-
past and now combination of interests is inevitable,
ll legislature stipulations will be evaded and restric-

sidering the practical side of the scheme, we are
question of "How is the Government prepared to
ch a scheme?" We could scarcely ask for more ad-
onditions. We already possess a Government railroad
ern seaboard in the Maritime Provinces to Montreal.
rtant link could probably be obtained in the Canada
way, thus bringing it one-third of the way across the
eyond this there would be an option of a water-route
arbor to Port Arthur; or a western extension through
ntry north of Lake Superior, which is of little value
umbering and mining. From Port Arthur to the
t for small sections the line would be in a producing
ying value, and would probably pay for its construc-
years' time. The extension to the Pacific should be a
nent. Thus we see that a railroad built by the
f efficiently handled, would in a short time be re-
national burden to a source of revenue, or at least a
ncern, while at the same time providing reasonable
rates for traffic.

ys Built by the Government, but Operated by
Private Companies.

ne is favorable in many respects, being the mean be-
rnment railway and a private railway assisted by

the Government. The portion of the route which would p
and cost least, is that through the prairie region. If, th
the Government were to provide an open highway betwee
water in the East and the eastern border of the great whe
ducing district (some point near Lake Winnipeg), and a
panies satisfying certain conditions were permitted to use i
companies building the lines through the prairies as com
undertakings, many of the difficulties would be eliminate
the problem. The Government road should be double tra
give the necessary accommodation. This would provide
for western produce, which would be gathered in by the
lines operating in the West, and brought to certain defini
at fixed transportation rates, of which the Government wou
absolute control. This arrangement would answer most
ments satisfactorily. The West would in time have the n
transportation facilities and reasonable rates insured. An
Canadian terminus could also be guaranteed.

(4) Government Assistance to Private Companies in Co
ing a Transcontinental Railway.

Recent developments have shown that this is to be
come, therefore a careful examination of the various sche
be interesting. When the problem came before the Gov
three concerns were seeking aid towards a transcontinen
way. There were, in order of precedence:

(1) The Mackenzie and Mann or Canada Northern
(2) The Grand Trunk Pacific.
(3) The Trans-Canada.

The Canada Northern.—

The Canada Northern is not a new scheme, but one w
been growing and spreading for the last few years. The
system consists of several branches running west from W
and a line connecting Winnipeg and Port Arthur and passi
of the Lake of the Woods. Maritime connections have be
by traffic arrangements with the Canada Atlantic Railway
land Steamship Line and the purchase of the Great Northe
way. By this agreement the Canada Northern handles t
and other produce of the West as far as Port Arthur, wh
taken over by the Canada Atlantic lake steamers and ca
them to Depot Harbor. Here it is transhipped into the
Atlantic cars and carried thence via the Canada Atlantic
and Great Northern Railway to Quebec, and shipped abroa
Leyland steamers. By the arrangement this steamship li
far as possible, to bring a return cargo which can be carr
the same route. Thus it is in a position for immediate c
to assist in relieving the strain in the grain traffic and, t

e private claims of the company, it is in the interest
that it should be pushed westward with all possible
country it enters is immediately brought into direct
th tidal water in the East.
ern system with its proposed extension is as fol-

nnipeg it proceeds westward in three branches, one
-west, passing west of Lake Winnipegosis, and turns
about 53° north latitude. This line is constructed as
l Deer River with an immediate destination of Prince
proposed extension to Edmonton. The second line
rom this about seventy-five miles west of Winnipeg
rectly towards Edmonton, having about fifty miles
The third line runs southward from Winnipeg for
iles, and thence westward, dividing into two bran-
ch going to Hartney and the other to Brandon. It
hat here is the nucleus of a comprehensive system
h of the fertile belt now without an outlet.
rn expansion is first to Edmonton, and from there it
approaches to the Pacific Coast; one by the Pine
d Skeena to Port Simpson, and the other by the Yel-
s and the Fraser River to Bute Inlet.
rn division is from Port Arthur, passing north of
, touching at Sault Ste. Marie and proceeding north
Bay to Gravenhurst. Extension beyond this would
ffected by the Canada Atlantic Railway and the
n Railway. This completes a brief examination of
orthern as it is and its proposed extensions, but be-
ng the details of the route, let us pass on to the
.

unk Pacific Railway.—

e scheme which is at present engrossing the interest
The platform held by its promotors is in the main
eals to the people as a promising agent for develop-
Vest and relieving the present congestion of traffic.
e details are unsatisfactory, and there is the invari-
nterests of different sections of the country, which
in launching any enterprise of such magnitude.
appeals are the development of the West and the
Canadian seaports, and it should be assured that
nt of the West be turned as far as possible to the
nprovement of our seaports.
g the scheme from a practical standpoint, we find
ce that the Grand Trunk Pacific has the moral and,
tent, the financial backing of the Grand Trunk sys-
ing it a substantial character. The portion of this

railroad through the prairie region, is the one of greates
mercial value, in fact the prime cause of its construction
proposed to locate it in a fairly straight line between W
and Edmonton, passing through Saskatoon. This line is
cally parallel to the Canadian Northern's proposed western
sion. Undoubtedly the country passed through is of an e
producing quality, but it is doubtful whether for the pre
least, there is a demand for two railways so close to one a
There are two approaches to the Pacific Coast proposed,
the Yellowhead Pass to Bute Inlet, and the other passing n
this with the option of the Pine and Peace River Passes r
the coast at Port Simpson, and sending off a branch to Da
is claimed that the country entered by this northern br
of good producing qualities, and the seaports are good, tho
approaches are difficult. Thus the Pacific section of th
would open up new, and it is claimed fertile territory, and
a new Pacific seaport.

The eastern portion of the route is the one which has
most difficulty in locating. From Winnipeg to Port Arthu
are difficulties of engineering only to be overcome. But
want the rail route to end here, and proceed eastward by a
route. This view is overruled by the "All-rail" supporte
propose proceeding eastward by a route north of Lake
and making the Port Arthur line merely a branch from th
line. The line would pass through Mattawa, and thence d
Quebec. This portion of the route would pass throug
country in Northern Ontario and Quebec, now comparative
known and thinly settled. Reports of various exploration
that the land is of good quality, well watered and containin
valuable timber and rich mineral deposits.

Quebec would be the summer terminus of the road,
transported material would be shipped abroad. Thus far t
out the whole line, although there has been difference of
there has been no serious objection to any part, but the
from Quebec, the summer terminus, to a winter one in th
time Province, has been the subject of bitter contention.
first place the Intercolonial connects Quebec with the variou
time ports, but it is claimed that its location is such as t
it unfit to form part of a transcontinental system.
to a certain extent true, but nevertheless the physical feat
the region render it impossible to shorten the line to an
extent, at the most 250 miles, and it would be, therefore,
cally parallel to the Intercolonial, killing the little traffic w
now possesses. Thus when all considerations are examin
nature of the traffic, the possibilities of the Intercolonial
season of operation to the Maritime Provinces, it must be a
that the construction of the portion of the line between

hould not be undertaken without a most careful in-
ıd examination of the engineering features to be

brief resumé of the scheme, showing generally its
ties and objections. Let us now glance briefly at
osition.

ıada.—

osition has now practically ceased to exist for the
st, but, nevertheless, it possessed some promising
might warrant its reconsideration at some future
ıte proposed is strikingly original, and throughout
ourse located through country practically unknown
ed.

t Quebec it strikes north-west to St. John Lake.
nt (about Chicoutimi) it extends directly westward
y unbroken line, passing north of Lake Winnipeg.
thern Saskatchewan and Southern Athabaska, and
ckies by Pine River Pass, reaching the Pacific Coast
on. As an agent for developing the country, such
be of the greatest value, but its commercial possi-
be very uncertain, and it would require years of
development before its tributary country would be
ondition. However, some such railway may be the
ure growth.

ing these railways the chief points to be considered

ıeral commercial facilities—country opened up, sea-

ical considerations that is the conditions tending
cost of transportation to a minimum.

ngineering practicability.

st the country requiring an increase of transporta-
most urgently, is that between Winnipeg and Ed-
of the Canadian Pacific Railway. About 80 per
district is an excellent quality of cereal producing
with the exception of the branches to Yorkton,
Prince Albert, it possesses no means of export, and
has been little opened up. This district should,
he immediate consideration. The Canadian Northern
ıtered this region, bringing with it an increase in
d agricultural activity. It has been granted a guar-
nds amounting to $13,000 a mile for the extension of
monton, a distance of from 600 to 700 miles of con-
Grand Trunk Pacific also enters this region. Thus
centre of the fertile belt would be supplied with a

comprehensive system of trains to which subsidiary lin
ce added as required. There is a considerable area to the
this which is claimed to be excellent producing country,
little settled and without an outlet. This would be partl
up by the proposed Trans-Canada. Thus we see that as f
West is concerned there is room for all three railways to
the necessary transportation facilities for the full develo
western Canada. Nevertheless, it would be advisable, th
pressing demand is from the centre, it should be conside
and as settlement extended northward the railway accom
could be increased.

Eastern Canada would be benefited by an increase
portation. It is particularly well adapted for this natura
rivers possess almost unlimited water-power which
utilized for driving flour mills, etc. Its many natural
render access to such points comparatively easy. Thus
continental railway would develope the producing
Western Canada and advance industrial and commercia
the East. Much of the good to be derived from such a
would not be an immediate consequent to its construction

The eastern terminus is one of the vital questions of
blem. In the first place it should be a Canadian port,
should be insured by taking advantage of our geographic
and not by legislature. Traffic will seek the shortest and
route, and any attempt to divert it into unnatural chan
be detrimental to trade. The Canadian eastern sea
peculiar as regards maritime ports. The north eastern p
inaccessable and unsuitable on account of the Arctic curre
St. Lawrence, though presenting exceptional advantages
mer traffic, is not available during the winter. This redu
the ports of the Maritime Provinces, but here the approach
cult and lengthy owing to irregular physical features.
principal ports are Halifax and St. John. They both
natural advantages, but are not yet equipped with adeq
minal facilities.

The question of the eastern seaport will probably be s
making Quebec the summer terminus, and Halifax or St.
both, the winter shipping port. Such an arrangement shou
satisfactory when fully equipped with elevators, docks, e
in comparison with American ports. The chief danger
score is with the Grand Trunk Pacific, as the Grand Tru
way already possesses a line from Montreal to Portland,
which it has equipped for handling grain, and it will, t
be difficult to keep the Grand Trunk grain traffic from
now its natural channel. Another consideration in co
with the eastern seaport is, that by shipping from a Canad
and keeping on Canadian territory the "Bonding privile

done away with. There is one more question transportation of grain across the continent. It ree or four days to make the trip, with probably evators at the terminus. It has been found by the more shaking about that it receives the better of the grain. This has been one of the strongest vor of the water route, and it has been considered ent ground for saying that grain will always seek ather than an "all-rail" transportation.

ical considerations which regulate the cost of re:—

ure of the road-bed-curves, grades, etc.
of construction and operation.
s for handling grain at the terminus.

at considerations in constructing a railway, are the tion and the cost of operation, and the engineer have to pursue a course intermediate between too ion and too difficult operation. The two prime ruction and operation are the grades and align- e are themselves often opposing factors. It is, ial that the proposed route be thoroughly investi- to procure a uniformly feasible and satisfactory

utmost importance that the centres in the West s in the East be adequately supplied with terminal s is an important factor in the cost of transporta- now an opportunity for the Government to assume portation rates. The present policy is to put on as affic can stand, in consequence of which Canadian three times what American railroads are charging. ay procure large dividends, but it is injurious to large, and Western Canada in particular. We es based on the actual cost of haul from the mar-

consider the engineering aspect of the problem. divided into four divisions of distinctive physical e are:—

eastern section—from the Atlantic to the height and between Hudson Bay and the St. Lawrence em.
height of land.
prairies of Western Canada.
mountains of British Columbia.

ada.

Canada there are no engineering difficulties of ex- st. Southern New Brunswick is rough and hilly,

thus necessitating heavy work or lengthening the line; alternative is the more practicable. The passage of the rence will probably be made by the Quebec bridge now u struction. Between Quebec and Mattawa the proposed north of the more settled districts, and passes through rough and varied country. In general, therefore, the rout Eastern Canada will be determined more by commercial gineering considerations.

(2) The passage of the divide.

This region is composed of a great belt of archean ro starts in Labrador and sweeps westward, passing north o lakes and extending into the United States. The easter of this belt is of considerable width and very aggressive The country is rough, but attains no great height and is ized by great abundance of lakes and streams. Proceed ward the belt becomes more concentrated and dist where it skirts the north shore of Lake Superior it is a of bluffs and ridges intermingled with extensive muske

The difficult undertaking of constructing a railroa this country may be avoided by utilizing the water-rout by the great lakes, but this being available only in s not altogether satisfactory. The engineers laying out the Pacific Railway decided to follow the Lake shore as fa sible, but this route introduced difficulties which could avoided by passing further inland. The road had to be c over the necks of the larger promontories and around of the bays, necessitating heavy grades and sharp curve

The Grand Trunk Pacific proposes to cross this re siderably north of the C. P. R. where, although the c essentially the same, it is thought that there will be struction and better alignment and grades. The Tra proposed an essentially different point at which to region. Starting from Roberval it struck off in the di James Bay, and by following river courses a route w which is claimed to be much superior to that of the Pacific. Wherever this country may be entered it will gineering skill to the utmost to construct a first-class r

(3) The Prairie Section.

The prairie section is the paying portion of a transco railway, and it would, therefore, be almost absolutely d by commercial considerations. This is rendered possibl fact that this portion of the route is almost free from en difficulties.

Mountain Division.

ive passes by which connection between the Pacific prairies is possible. These are the Crow's Nest ing Horse Pass, the Yellowhead Pass, the Pine lastly, the Peace River Pass. The Kicking Horse rst one used, and it was by it that the first trans-nections were made. The route led over the Kicking Horse Pass, then followed the Columbia distance towards the north-west. The Selkirk sed by the Roger Pass, thence the line followed r and reached the coast at Vancouver.

route is from Edmonton south-west along the r and crossing the Rockies by the Yellowhead nues westward by the valleys of the Fraser and Port Simpson.

m Edmonton a third route is possible by the Pine r the Rockies. It follows the Pine River as far as nd thence south of Stewart and Babine Lake and of the Skeena to Port Simpson.

te is from Edmonton north-west, then along the lley over the Rockies, and thence via the Babine ers to Port Simpson. The country along the Peace claimed to be excellent agricultural land and the it may, therefore, prove to be a valuable piece of lement when opened up.

on, the western terminus of the proposed railway, cellent harbor, but the approach is difficult.

etes a rough sketch of the chief engineering fea-t with in constructing a transcontinental railway. would now require about five years to develop with of from $13,000 a mile in the prairie section to mile in the more difficult portions.

, apart from the commercial aspect of the scheme greatest national importance. Although Canada extent of country, there is comparatively little of operation. The construction of any one of these aid in giving length and breadth to the country, developing much that is now almost unknown, and e advance of the country as a whole. It marks t stage of development of Canada, and, if the anced sufficiently to require a second transcon-, it is worth the sacrifice which it would entail.

PAPER No. 217.

MECHANICAL WOOD PULP.

By Stanislas Gagne, S. Can. Soc. C. E.

At a time when so much emphasis is laid upon Cana
dustry and Canadian manufactures, when "Made in Car
used as a sign to catch the market of the world, a review o
nical Wood Pulp, an industry which not only at present co
an important asset in Canadian wealth, but which pro
become almost a monoply in the future, should be opport
interesting.

It was the discovery of ground wood pulp as a paper
material in 1845, that first afforde1 an opening for the gr
this industry in Canada.

Mechanical Wood Pulp is adapted to many other uses
that of producing paper, but it is as a paper producer
future is assured, and it is chiefly in this connection that
cess will be considered in this paper. Before entering i
however, upon the process involved in the manufacture of
cal Wood Pulp, a sketch of the essential components of p
of the different materials employed in its manufacture
given, that the efficacy and utility of the mechanical proc
be judged by comparison.

Typical paper consists of approximately pure cellulose,
ted together as to form a sheet.

Cellulose.—

Cellulose may be termed the material basis of the
world. When pure, it is a white, translucent, tasteless,
substance without nutritive power, insoluble in water, alc
oils and a little denser than water.

For paper making purposes, cellulose fibres are deriv
two main sets of sources; in the first place, from cotton a
rags, esparto, flax (spinner's waste), hemp (old rope), ju
and sugar cane; and secondly, from different kinds of wo

In all the fibres derived from these sources the follow
perties are requisite. They must have a certain length, th
be small in breadth or thickness, they must be flexible
well.

The felting power depends specially on the structur
individual fibre. An example of a good felting fibre is t
(not a paper making fibre, being of animal nature). As

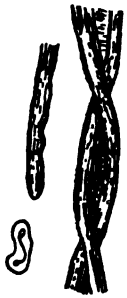


Fig 2
Cotton Fibre

Fig. 3 — Flax Fibres
a shows creasings from bending

lls

Fig.5—Spruce Structure

Fig. 6
Birch Fibre

Fig 8
Spruce Fibres

Fig. 9
Ground Spruce

figure 1, the wool-fibre is discontinuous, consisting appa imbricated scales; these brought together tend to interloc as silk nores (also of animal nature), for example, being d ders perfectly smooth, simply slide over one another whe or pressed together.

We shall now take a short glance at some of the co sources of cellulose fibres as enumerated above, and see degree they possess these different properties.

Cotton.—

Cotton fibres are the purest cellulose available in state. They are long, thin and rather rough, and when to roll themselves around their axis, hence they felt well 2 shows the form and structure of a cotton fibre. The which usually reach the paper maker in the form of waste, form the basis of most high grade book papers, enter, in different degrees, into the composition of n grades.

Flax.—

The fibres of the flax are long, strong and flexible; often jointed and cut up, and are capable of lengthenin breaking. They reach the paper maker also in the form of spinners' waste, and produce a very strong paper (line which, however, is not so compact as that manufactured ton. See figure 3.

Hemp.—

Hemp fibres resemble very much those of flax, but a and stronger; especially is this true of Manila hemp, w stitutes the basis of the real *Manila paper*. These fibre reach the paper mill in the form of old ropes and rags.

Straw.—

The fibres of the straw are little adapted to paper m the cheapness of this raw material in such countries as west, renders its use economical. Straw fibres are shapes, some being long and slender and fairly unifo some are in the form of smooth pith cells and of serrat mal cells. See figure 4.

Sugar Cane.—

Cane thrash or bagasse has been recognized as a material for rough paper, as its fibres possess great str has been claimed that it is stronger than Manila hem value for book paper has yet to be demonstrated. Like a very cheap by-product in southern countries.

WOOD.

ie above mentioned sources of cellulose are available
aratively small quantities, and as such the paper
iem merely to get special grades of paper. On the
e great bulk of our manufactured paper is derived

peaking, wood may be said to be composed of cel-
emented together. These bundles of cellulose fibres
m of long cells, also cemented together, which are
l to the longitudinal axis of the tree. See figure 5.
hemical composition of wood is 50 per cent. carbon,
drogen and 44 per cent. oxygen. Taking poplar and
examples, their physical composition is as follows:—

	Pine.	Poplar.
ge of Cellulose..	53.3	62.8
" Resin..	2.0	1.3
" Aquaeous Ext..	1.2	2.9
" Water..	14.5	12.1
" Lignin..	30.0	20.9

ntities vary with different qualities, especially in the
The following is the percentage of cellulose for dif-
—

ar..	62.8
r Fir..	56.9
ow..	55.7
n..	55.5
.. ..	53.3
ce..	53.0
tnut..	52.6
h..	45.5
y..	30.0

of these different kinds of wood as pulp producers
hat more on other properties than on their percen-
se, as will be seen later. Nearly all our Canadian
d may be employed for pulp making, but in actual
umber of kinds is limited; hence we shall consider
d in our Canadian pulp mills, and more especially
d by mechanical wood pulp manufacturers, viz:
d, poplar and aspen, hemlock, pine, fir or balsam and

of the birch are white, long and in breadths or
in different parts of the same fibre; they are, as a
nd exhibit numerous markings in the form of slits.

See figure 6. Only a limited quantity of it is used in Can mostly all by chemical processes. It makes a fine grade

Basswood.—

The fibres of the basswood are very similar to thos birch. They are employed more than birch as a paper and give a fine grade of paper, strong and soft.

Poplar and Aspen.—

The fibres of the poplar and aspen are among the b fibres for paper making. They are white, long, thin and and resemble closely, in appearance, the birch fibres; so joints and extend in the form of a tail, see figure 7, but lacking in great strength. They are used for fine book they are capable of acquiring a fine gloss. They are pulpe sively where a large supply is available, but the difficulty ing sound wood renders the operation sometimes rather e Poplar and aspen apparently sound to the eye is very fr through certain districts, discolored and rotten at the hea "*black heart*" must be removed, as its presence renders very inferior in quality in proportion to the quantity of colored and rotten part.

Hemlock.—

The hemlock furnishes a coarse and rather brittle fibre color and suitable only for cheap paper. Generally speaki used only where the supply of other woods becomes short.

Pine.—

Pine fibres are brown in color, long, flat and broad, th are tapered and are characterized by oblong openings whi trate through them. This wood is used but in few places an by chemical process. It produces a brown paper speci adapted for boxes for sugar confections.

Fir or Balsam.—

The fibres of the fir or balsam resemble those of th described below and are, like them, white, long, thin and str found in different parts of Canada, this species contains quantities of resin, a fact of much consequence in its va pulp producer. Where it contains little resin, it ran spruce as a raw material, but where resin is present in lar tities, it is detested by the manufacturers. In the chemi cess much difficulty is experienced in removing the resin the mechanical process no end of trouble is occasioned resin in the various parts of the machinery.

Where little resin exists, as much as 25 to 40 per cen or balsam is used with spruce, and when largely resinous ten per cent. is considered plenty, and none at all much be

sical composition of spruce, as given at the beginning
e on wood, shows that it contains 53 per cent. of cel-
its other constituents resembling those of pine. Its
nite, long (from 1-20 to 1-5 of an inch), thin (from
00 of an inch), broad and flat, rough, strong and often
ey are characterized by the presence of numerous pit-
cups, circular and elliptical; see figures 5, 8 and 9.
la we have mainly three kinds of spruce: The *black*,
d the *red* or *grey*; these colors refer chiefly to the bark
essarily to the wood fibre.
k variety is that which stands in most favor with all
acturers. Its fibres are the toughest of the three
d are fine and white. It grows very thickly in swampy
as the Laurentian areas, where it is easily recognized
bark and long stem with only a bunch of leaves at

te variety grows specially on dry ground, and its fibre
eaker than that of black spruce, but somewhat whiter.
s a fine grade of pulp.
nes *grey* or *red* spruce refer, the first, to the color of
d the other to that of the wood. Its fibres resemble
white variety, but have a pinkish color.
hree varieties of spruce form the basis of the wood
y of Canada, and in the majority of the mills spruce
exclusively, especially for mechanical pulp. They fur-
st wood fibres for paper making, and our immense
pply renders them a most economical raw material.
be added to this description of wood, and especially as
ace, that trees of slower growth produce the longest
t fibres; for example, spruce grown on poor soil or in
s, or again in cold climates, give better fibres than
in richer soil and warmer climate. For these reasons,
n in Newfoundland or near the Labrador Coast, gives
ade of pulp than that grown farther inland and south.
reasons also, Canadian spruce furnishes better pulp
rown on the soil of our Southern neighbors.

Processes.

owing is an outline of some of the different processes
g fibrous material or pulp from the above mentioned
n all processes, except perhaps the mechanical, the
s to obtain the cellulose fibres pure and individual.
flax and hemp are used, as said before, in the form of
te, which are first boiled to cleanse them, then beaten
the fibres and bleached. Straw and bagasse are treated

by chemical processes suited to their composition; they s
pulped in Canada.

Wood is treated by two kinds of processes, viz., the cl
and the mechanical. In Canada we have mainly two c
chemical processes; the alkaline or *soda* process, and the s
sulphite process. The action of the chemicals in both case
dissolve the non-cellulose constituents or the cementing m
of the wood, thus leaving the individual fibres.

Soda Process.—

Twenty-five years ago the soda process was consider
most economical of the different chemical processes. It wa
developed in America in 1853, by Watt and Burgess; and i
M. M. Angus, Logan & Co., of Windsor, Que., were makin
pulp out of basswood.

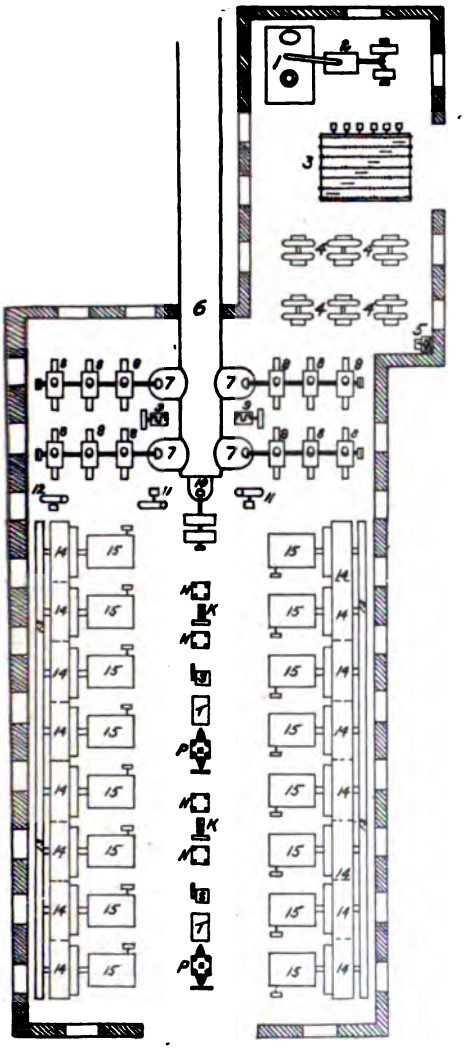
In this process the wood is first barked and chippe
packed in digesters, which usually consist of cylindrical st
iron tubes capable of containing two to three cords of wo
nine to ten per cent. solution of sodium hydrate is put in, a
whole is raised to a high temperature and pressure by adm
of live steam. This "cooking" lasts from eight to ten hours
which the pressure is partly taken off, sufficient only bei
tained to blow the mixture out in tanks, which is immed
done. This mixture of a brown black color is washed wit
water and the diluted liquor is conveyed to tanks and wa
where the soda is mostly recovered in the form of ash. Th
then consists of the individual fibres of the wood employe
colored light brown by the digesting liquor; it is after
screened and bleached, preparatory to its being transforme
paper.

All the woods mentioned and described above are, or m
treated by this process, but poplar and aspen are the best ad
to it, and in fact they are nearly always pulped thus. T
also a good method for pulping birch and basswood, but s
fir and pine are more difficult to treat. Woods are never
in the same charge of a digester.

The yield of air dried fibres is from 30 to 35 per cent. o
wood employed, which shows that from one-third to one-half o
cellulose has been destroyed.

Sulphite Process.—

The sulphite process is comparatively new and has se
advantages over the soda process which caused most of the
built lately to adopt it. The advantages are these: The
of chemicals is less, a larger yield of pulp is obtained, the fib
not weakened by the process, and the paper made from it is h
and more transparent.



), General Plan of a Mechanical Wood Pulp Mill.

am boiler; 2, steam engine; 3, sawing machine; 4, bark-ine (in pairs); 5, splitting machine; 6, water flume; 7, and casings; 8, grinding machines; 9, pressure pumps; 10, d turbine for general work; 11, Stuff pumps; 12, low pump; 13, troughs; 14, screens (vibrating type); 15, ines; H, hydraulic presses; K, high pressure pumps; S, , tables; P, packing presses.

In this process the wood is barked and chipped as in t
process; some manufacturers remove the knots and other
ties, which are but little acted upon by the chemicals, while
claim that it is more economical to remove them afterwards
screens. The chips are dumped into the digester, which is
clad cylinder, vertical or horizontal, or perhaps also rotar
with some material not acted upon by the acid; in the pa
was employed for this purpose, but in later practice, a l
four or five inches of Portland cement has been found t
well. In a digester of a capacity of two cords, 2,500 gallo
3½ per cent. solution of an acid sulphite is put in and liv
is turned in, thus raising the temperature and pressure.

The constitution of the wood lends itself to the forma
certain organic sulphur acids (sulphonates), which greatly
tate the process. After 10 to 12 hours of "cooking" the
blown out into tanks, where it is washed; the liquor in th
however, being usually dumped into the nearest stream, th
only being preserved. In this case also the pulp consists
individual fibres, which after being washed, screened and b
are ready for the paper machines.

As in the case of the soda process, all the woods abo
cribed may be "pulped" by this method, but spruce is t
adapted and the most employed.

The yield by this process is usually 40 to 50 per
the wood employed, which is quite an excess over that
soda process.

There are many other so-called chemical processes for i
cellulose from wood, but as they are not used in Canada,
likely to be for some time at least, they are of little imp
to us.

Outline of the Mechanical Process.—

In the mechanical process the wood is first cut into 1½
foot lengths and barked. These blocks are then pressed
revolving sandstones, which grind the wood to a pulp.
again, after being screened and bleached is ready for th
machine; but as our mechanical pulp is nearly all made fo
ation, it has to be transformed into a convenient shape f
ment. For this reason, the mechanical process as usually
stood, also means the use of "wet machines" to put the p
the form of sheets, and also of hydraulic presses to ext
water from these sheets, and of packing presses to put th
proper shape for shipment.

The above description of materials and processes h
given to enable of a full understanding of the aim and o
pulp making, and to furnish a basis of comparison. We sh

ention to a fuller description of the *mechanical process*, main object of this paper.

THE MECHANICAL PROCESS.

of this process is likewise to produce cellulose fibres aking, but being purely mechanical the whole solid the wood except the bark is ground into pulp. As we fore, spruce for example, contains only 53 per cent. of es, hence, mechanical pulp made from spruce can only er cent. of paper making fibres, the rest being called, at the beginning of this paper, the cementing material nly lignin. This is the reason why paper partly made l wood pulp, such as newspaper for example, dis- exposed to the light for some time.

the wood is ground on stones, we have the pulp in minute chips, and not as individual fibres as in the chemical processes. Therefore, this process gives a result from the others described, which places it in self. It is not, however, a rival to them, each kind n use. It is the direct object of the manufacturer in however, to get as nearly as possible a fibre pulp, a h depends the value of his product.

ed.—

specially the black variety, owing to its tough fibre other reasons seen before, is mainly employed.

lsam is also used from five to even as high as 40 n spruce as also seen before; when ground its weight spruce, and consequently more wood is required to n of pulp, and is more bulky when baled. When dheres to the stones, chokes the screens, clogs the the felt of the wet machines, causing irregular sheets trouble everywhere in the process.

nd aspen, when ground, make a fine, white and of pulp, but as their supply is nearly always limited, also limited. Spruce and poplar or aspen make a tion, spruce lending its strength, and poplar or aspen the pulp.

ods of cutting and bringing wood to the pulp mills as in the case of ordinary saw-mills, the only excep- at all the wood of a tree is utilized save the branches; logs as small as three inches in diameter are brought s the size of the blocks is really of not much impor-

illustrates the general principles adhered to in the pulp mill. No definite rule is offered for the arrange- nachines, each individual site having its own peculiari-

Power.—

All mechanical wood pulp mills in Canada are situa
some water course or stream from which the necessary p
derived and, in most cases, on which the wood is floated
mill. As a rule steam power cannot be used for this pur
account of the large amount required, on account of th
variations of the load, and its cost; a water fall, natural o
cial, is the only source of power that can be utilized for
mill.

An ordinary grinding machine producing five tons
(dry) per 24 hours, requires about 350 H.P., and an additi
will drive the rest of the machinery for those five tons, th
75 H.P. are necessary to produce one ton of pulp (dry) in a

Since it is not the purpose of this paper to discuss the n
of utilizing a water power and the means of getting the
power from a given fall, a few remarks concerning the 'r
ments of the process will be sufficient.

A dam or canal, or perhaps both are built, and from
penstock, flume or pipe line conveys the water to the turb
water-wheels. The types of these wheels are governed
height of the fall; by the variations in the volume of wafe
able, and by the work that is expected of them; the usual
being to use re-action turbines for low heads, and impulse t
for high heads. As will be seen later, some such speed
to 250 R.P.M. is required, and this ought not to vary whe
of the load is taken off, as when pockets of the grinders ar
filled, thus relieving the pressure on the stone. To atta
result, governors are sometimes employed, especially when
drive only one or two grinders each, for then, one pocket
means $\frac{1}{3}$ or $\frac{1}{2}$ of the load suddenly taken off, and in suc
the turbine will increase in speed according to its construc
no governor is attached to it; but the cost, great wear, fre
of repairs and losses of time occasioned by these, mak
manufacturers try to do without them if they possibly can.

As will also be seen later, pumps are sometimes used
as governors, but as their use as such means a different g
pulp at different times, they are unsatisfactory for this p
The best means of getting over the difficulty seems to be to
on one pair of turbines, turning both in the same direction
to their common shaft, as many grinders as possible. If a
turbines are thus attached to each other as in the case of
10, the friction on the end bearings will be eliminated, th
creasing the efficiency. In some cases turbines m
built so that variation of speed will be small compare
certain variations of load, thus dispensing with governors.
turbines may be designed for a given speed when some of th
kets of the grinders are idle, and in operation, when the p

om one pocket, the same pressure is automatically
nother one, thus keeping the load, and thereby the
nt. Therefore, the problem is this: Given a certain
ume of water, to get a turbine that will give a good
a given speed, and that speed not to vary over much
variations of the load. To fulfill these requirements,
o to get any turbine whatsoever, being guided by its
other such considerations.

ain proper order in this description of the mechani-
we shall start with the wood as it arrives near the
ere lumbering operations proper end and follow it
ifferent parts and machinery of the process.

.—

re floated down the river, they are kept in a boom
ll dam, from which they are taken to the cutters by
ide, chain conveyor and log jack or a similar arrange-
ing on the nature of the ground relative to the mill.
y cars they are dumped near the mill, where some
such as an endless chain distributes them to the cut-
ar device is used if the logs are brought from the
he mill or taken from the piles of the winter supply
een laid on skidways at the fall before the river was
of the rules that should be observed in handling
ep them out of contact with the ground as much as
use sand and dirt will occasion trouble when they
barked.

l should also be employed as green and wet as pos-
the grinding operation is thus facilitated and the
higher grade, as the fibres are more flexible and not
tach from each other.

are cut into lengths regulated by the size of the poc-
rinders, usually 24 inches, though some use as small
ngths. For mills of a small capacity, say up to 30
a swing saw is generally considered a good arrange-
lly when logs are from 10 to 14 feet long.

gs are brought to the mill in four foot lengths (cord
adle saw is sometimes used, where logs are put on a
is swung to the fixed revolving saw.

e best machines for sawing these blocks, when the
rge capacity and output, is that represented by figure
case each saw is on a separate shaft, and all these
re driven by the same pulley and belt. Logs are
the table by endless chain conveyors, and in this way
is cutting a log at one time. If more than one saw

is made to cut a log at one time, that log is liable to jam b the saws, damage them and fly out, specially if three saws o are used. By this method, illustrated in figure 11, when a l passed across the whole table it is all cut up into the re lengths, which fall nearby or are conveyed to the barkers.

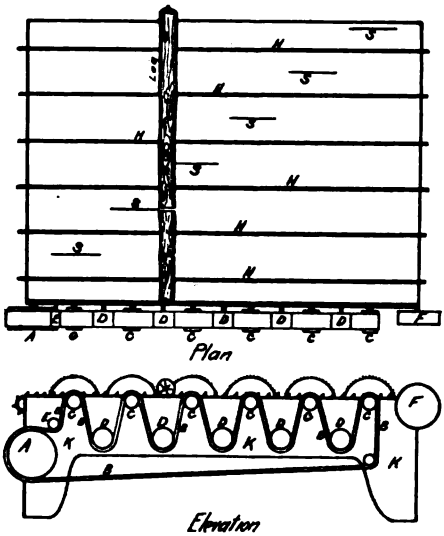


Fig. 11. PRINCIPLE OF A PULPWOOD SAWING MACHINE.

A, driving pulley ; B, driving belt ; C, saw pulleys ; D, tightening pulleys ; E, tightening pulleys ; F, conveyor ; K, frame ; H, chain conveyors ; S, saws.

Barking.—

The type of barker most frequently employed is that sented by figure 14. It consists of a disk about 52 inc diameter, in which four knives are so set as to cut a thin sl the wood stick at a time. That disk is surrounded by a cas frame, open to give access to the knives, and a table to s the wood is attached to it. The bolt or stick is pressed a the revolving knives, and the bark and chips falling behi disk are blown by fans acting like centrifugal pump, thro pipe to a convenient place, usually to the boiler to be utili steam generation. The wood is usually pressed and re against the cutting knives by hand. Various arrangement

to revolve the wood automatically against the knives, stion whether such a plan is useful and economical. revolution of the wood stick, in these automatic iances, depending as it does on that of the knives, do good work and save labor if the bark is of uni-, but in cases where logs are brought long distances through rapids, the thickness of the bark is very in facts, parts of the stick have no bark at all;

PULPWOOD BARKER (Sherbrooke Iron Works).

sticks are put into an automatic revolving apparatus ood will be cut unnecessarily, whereas if revolved ark only will be cut away.
ty of an ordinary barker running at about 600 R.P. from six to ten cords a day, varying with the skill r.

ks are too large to enter conveniently into the poc-inders, they are split. In those cases, which fre-where pulp mills are provided with a carriage and g large logs into lumber for the market, instead of to produce pulp, little splitting is required after

ily found convenient to have the sawing, barking operations all performed in a separate building as eral plan, figure 10. Power for this purpose may be

derived from one of the turbines or from a steam engine, and small butts being used as fuel.

From the barkers the wood is conveyed to the grind

Grinding.—

What constitutes the mechanical process of "pulpin is the grinding operation instead of a "cooking" with c hence if mechanical wood pulp is badly ground it will b in quality, no matter how well other operations have formed.

We have seen before that wood is an agglomeration and the object of grinding is to derive from that agglom pulp or a soft mass of particles that will have the proper for paper making, viz., be long, thin, flexible and felt w attain this end we have several kinds of grinders which little in principle.

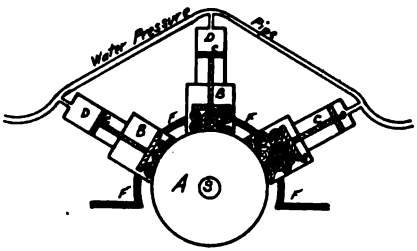


Fig. 12

Sectional Elevation of GRINDER

A, stone ; B, pocket ; C, piston ; F, frame ; S, shaft.

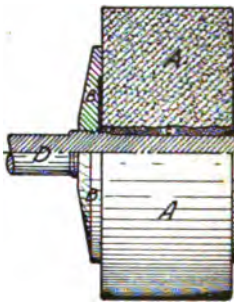


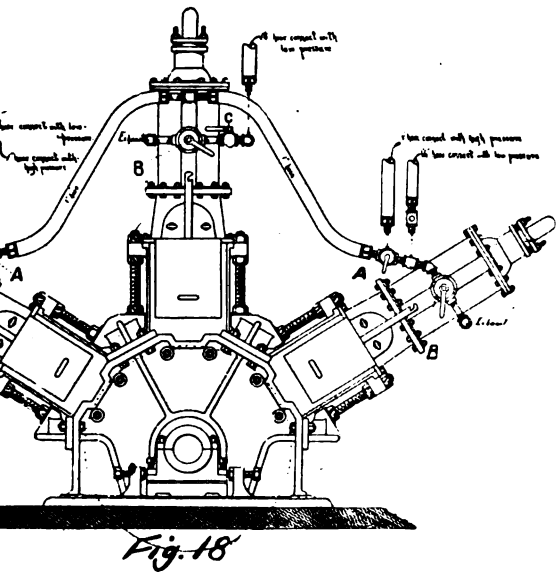
Fig. 13 STONE & FLA

A, stone ; B, flanges ; D, shaft.

Figure 12 illustrates the principle of an ordinary grind have first a stone *A* against which the wood sticks or bo their longitudinal axis parallel to the shaft turning the st pressed in pockets *B* by hydraulic pressure on piston cylinders *D*.

These stones, which must be composed of very small an grains, and have a certain strength to resist the centrifug caused by revolving at a high speed, are quarried out stone and turned to required dimensions. Some good sto quarried in Nova Scotia, but the best ones are said to b derived from certain districts in England.

Port Henry Grinder built by the Jenckes Machine
oke, Que., as a typical example of the kind which
ada, the following is a general description of the
e name of the chief parts may be obtained by
re 12. The shaft, which is very large, is made of
teel, and on both sides of the stone are threads on
es are screwed. These flanges which are about 38
ter, are faced where they come into contact with
igure 13); threads are cut right and left, and they
lbs. each. This grinder, which is so made as to
50 to 54 inches in diameter and 18 to 26 inches



Port Henry Pulp Grinder.

until the stone is reduced to about 40 inches in
main shaft boxes or bearings are self-adjustable,
orm themselves to any variation in the shaft. The
ox is about 18 inches, wood lined for bearings in
tted boxes are sometimes used with them. The
le in one piece, two inches in thickness, and can
ed to the stone so that very few splinters can pass
d. The middle pocket will take wood 16 inches
the two side ones, 14 inches in diameter, hence

the use of a splitter is largely dispensed with. The p
raised or lowered in the sides on planed surfaces by
soft steel screws (S). The doors for the pockets are o
plate, and slide up and down in a groove in the po
pocket followers are provided with strips last on the lo
prevent the wood from rolling in the pockets. The cy
made of iron, lined with brass, and have heads accur
to them. The lower heads connect direct to the top of t
and are provided with doors on the back and front,
easily removed when lower packing glands of piston r
adjusting or repacking.

Operation of their New Piping System (Patented).—

Referring to figure 18, suppose the two side pockets
ing under high pressure and that one of the side poc

Fig. 20. Pulp Grinder, manufactured by Carrier, Lane

refilling; the centre pocket is then idle, but by changing
way valve *A* the high pressure is thrown on to the cen
and causes it to grind under high pressure. The empty
ket being now relieved, the low pressure water au
opens the check valve and acts upon the piston, lifting
follower from the stone. The pocket is then refilled.
B is shifted, allowing the low pressure to bring the pi
until the wood is pressed firmly against the stone. At
the three-way valve is turned so that the high pressur

the centre pocket and enters on the top of the pis-
ne time automatically closing the low pressure check
ntre pocket is now idle, and if the other side poc-
filling, it is done in a manner similar to the above.
the centre pocket should require refilling, the fol-
entre pocket is lifted from the stone by means of
n is always connected with the lower pressure, the
ed and the low pressure again introduced into the
the piston. In this manner, as above stated, the
always filled with water at a high or low pressure,
when the three-way valves are shifted there is no
efore the pockets begin to grind, and the grinder is
action.

r built by Carrier, Lainé & Co., of Levis, Que., dif-
above mentioned, as seen by figure 20. Its construc-
he pulp to remain longer around the stone,
with part of the lower side in pulp and water, while
e usually intended to run clear of the water under-
rections of the pressure on the stone of the latter
ne as on the others, more distance being allowed
ockets. Some objections are made to this method
the pockets, because the horizontal thrust on the
one of the side pockets, when the other is not
great that it quickly wears out the bearing; and
the more vertical the resultant pressure is, the bet-
ring.

rinders—Stone Setting.—

generally made to run direct on the turbine shaft
ate the loss of power caused by belting or gearing,
d to it by means of two flanges, which screw in
ions on the shaft as described above, and so ar-
pressure on the revolving stone will tend to tighten
not loosen them. Care is taken to centre the stone
when the flanges are screwed up tight, cement is
nd the shaft and between the stone and the flanges,
holes made in the flanges for that purpose, to fill
that may be left so that the stone may be set
here.

that it is an improvement to bolt the stone and
inch bolts running through the stone from side to
on being that this adds to the strength and solidity
and prevents it from bursting. Others who tried
it, because they claim it causes the stone to break;
this is, that the stone is bound to slip sometimes

when a heavy pressure is suddenly applied; this it canno is bolted tight and the flanges cannot screw any more, and alternative left to the stone is to break.

Turning.—

This is done by means of an arrangement repre figure 21. ,The jig B is pressed against the revolving sto it requires turning, and is actuated by a screw and har

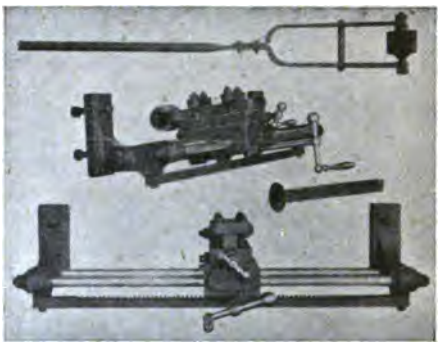


Fig. 21. Stone Turning device for "Success" Pulp Gri

The stones are usually thus dressed with a slight crow centre, or with the edges slightly rounded off to prevent of the stone; great care is taken that no cracks are mad stone which would cause it to fly off when revolving un sure.

Sharpening.—

This is the next operation, and a very delicate one most cases the value of the pulp depends on the skill wit it is performed, as may readily be seen. A perfect sh would be one such that the surface of the stone would posed of a large number of very small, sharp points or pr which would detach the fibres one by one. In actual prac nions vary greatly as to how to produce a good sharpeni mostly every case, a steel jig or burr, about three inches three inches in diameter, with pyramidal projections nu 16 to 100 per square inch is used, but it is in the use of that opinions vary so much. Some manufacturers emp jigs, a close pointed one, so as to make even cuts, is pas the surface, which is afterwards somewhat smoothed do a coarser jig. Others make use of but one jig, usually pointed one, which is passed several times over the surfa the latter is judged to be in proper shape.

seems to be a reasonable method, is to pass a sharp and se pointed jig (with say 100 projections per square inch) ross the surface of the revolving stone so that it will not the same surface twice, thereby causing an even surface 00 projections to the square inch on the stone.

lgs should not be used, as they make pits instead of jections. If the stone has been sharpened too much, a plane surface stone is used to smooth it. Some stones en by use instead of dulling, in which case they must be instead of sharpened.

requency of sharpening depends mainly on the quality ne and on the speed and pressure used; for an ordinary one with a 50 to 75 pds. pressure per square inch in the and a speed of 225 R.P.M., twice a week in summer, and in winter is a fair average.

sharpening, the stone is washed to remove all the loose sand, and then is ready for operation.

ockets are filled with wood and the turbines started.

maintain that the maximum production of a grinder en the stone revolves at a speed of 175 to 200 R.P.M., rs claim that a speed between 225 and 250 R.P.M. with y 44 to 50 inch stone produces the best results. Which The result only tells. Assuming the same sharpness ne and the same pressure on the wood, the production vith the speed up to a certain point and then decreases; ality of the pulp also increases up to a certain point and ases, but the quality is decreasing when the production ues increasing. If the speed is too low, the pulp will and if too high, it will be mealy and short. To find the int, both in speed and pressure, a careful examination ade and several tests of the product must be applied.

linary grinder, with a 50 inch stone, using 24 inch bolts g at a speed of 200 to 225 R.P.M. with a pressure of 60 er square inch in the cylinder, corresponding to a pres- to 18 lbs. per square inch on the grinding surface, will to 350 H.P. to produce five tons of air dry pulp per 24 ith 500 H.P., a pressure of 100 to 125 lbs. per square 00 R.P.M., it will produce seven to eight tons in the d.

le plates of the pockets should be set down as close to as possible to prevent chips and splinters from passing ground.

pply of water required to keep the stone at the proper e and to wash down the pulp, is usually introduced from the top and must be carefully attended to. When the

lower part of the stone runs into a vat partially full of p
water, the spray must be just enough to wash the pulp dow
water should be so regulated that the stone is kept at a
high temperature (about 100 degrees Fah.), which cau
grinding to be more easily accomplished, hence the outpu
increased.

In cases where the mill is stopped for repairs or for
care should be taken that the stone is allowed to cool slov
if the lower part runs in water, that the water is draine
that the stone may cool evenly.

The reason why stones crack and fly off when runnin
sumed, may sometimes be looked for in the overlooking
details.

Sometimes the wood jams in the pockets, thus relie
pressure on the stone, which then ceases grinding the
that pocket; in that case it is only necessary to remove t
sure and loosen the wood by means of a short bar. Th
sides of the followers should have strips cast on them
prevent wood from rolling in the pockets, as seen in the
the Port Henry Grinder.

An ordinary good English stone properly handled a
ated, lasts about a year and wears down in ordinary grind
54 to 40 inches.

If several stones are coupled directly on the turbine
in the case of figure 10, each one has its shaft length, whic
are all equal and held together by ordinary couplings.
should be provided with extra shaft lengths, and at l
ready mounted stone; thus, when a stone anywhere on t
has to be changed or replaced, the turbines are stopped
time necessary to uncouple the old stone and replace it
ready mounted one, which requires but a short length o

All grinders used in Canada are of the horizontal runn
as described above. In some other countries, however,
types are used and the grinding is done cold. Other ty
also been invented, but so far as the writer knows none
proved to be more economical and practical than the pre

Pumps.—

At least four sets of pumps are necessary for an ordi
porting pulp mill; 1st, high pressure pumps for the cyli
the grinders; 2nd, low pressure pumps for backing cylin
tons, for sprays on the stones and in screens and wet
and various other uses; 3rd, stuff pumps to convey the gro
from the tanks under the grinders to the screens, and 4
pressure pumps for the presses. In case of a mill der
power from a high head, the number of pumps may be re

pressure direct from the flume or water pipe being
f the first two.

Cylinders of Grinders. Ordinary triplex power pumps
sizes varying with the work to be done. At least
yed, and are so arranged that if one fails, the other
rk without any of the grinders being stopped. They
iven by means of a belt from the turbine shaft and
ure varying with the speed, they will act somewhat
if desired. If a constant pressure is wasted an accu-
d to regulate it.

ure Pumps. The same type as the one above men-
lt lighter will answer the purpose.

s. As the turbines must be set as near the tail race
most cases not higher than about 15 ft.), the ground
pumped up to the screens above the wet machines.
falls from the grinders into tanks or troughs running
r the grinders, and is conveyed by gravity to one or
irs from which the stuff pumps take it. On account
low head to be overcome, and of their simplicity and
valves, centrifugal pumps are the best adapted for
Ordinary stuff pumps are sometimes used.

sure Pumps for Presses. These will be considered

pulp falls from the grinders, enough water is added
it fluid and on its way to the reservoirs, it passes
l plates, which retain the chips and splinters which
unground. It is again diluted here and is pumped
ividual screens or into a long distributing trough
ens.

only two types of screens are used, viz., the rotary
and the vibrating, the former type being the newest
mmonly used as the latter. Although they work dif-
ll be seen later, their object is the same, viz., to
ell ground from the badly ground pulp.

separate the pulp into several classes, according to
fineness, but the majority make use of only one size
or slits, all the material not passing through these
rejected; but it is a self-evident matter that it
omical to use all the product of the grinders if a
e found for it. We will confine our remarks to but
or separation and describe some of the methods by
omplished.

Vibrating Screens.—

They consist of, first, a wooden box, at the bottom are the screen plates; below these plates is a di which are the screen plates; below these plates is a di which is made to vibrate up and down by means of a s cam. The pulp held in suspension in water is admitted ov plates by pipe and tap from the long trough containing th and a downward movement of the diaphragm draws or s material through the slits in the plates; the next upwar ment blows the slivers and other coarse material out slits, the two actions constituting a vibration.

The box receiving the stock over the plates is usually wood and so hinged that it may be lifted over the rest of chine. The frame containing the plates is also hinged mits of being raised for examination and cleaning. The plates are made of brass about 12 by 40 inches in size, and inch in thickness, with slits or holes two to three inches l from .008 to .020 inch wide, according to the nature of th to be screened and the fineness of the product required. nection of the diaphragm to the sides of the box is usual by india rubber of suitable elasticity and strength. The or shoes transmitting the vibrations from the cam are us wood, and are protected by cast iron and bolted casings vent them from splitting. The cam is rigidly fixed to th and is made of steel; it is so arranged as to give one, two, four throws each revolution according to the speed of th and to the rate desired by the manufacturer. These cams arranged on the shaft, that the strain on the driving belt form throughout each revolution. One or two springs ar around or near the shoe, so that it is always kept in cont the cam, shock and noise being thus avoided.

The capacity of such a screen containing 10 to 12 p four cams varies with the speed, the size of the slits quality of the stock. With No. 8 to 10 slits, ordinary well pulp and at a rate of 400 to 600 vibrations per minute, it two to three tons per day; and with No. 10 to 16 slits, fr to six tons.

The screens are often arranged in a row as seen in fi above the wet machines and either separate or forming tinuous trough. They are provided with an additional bo ceive the screened stock, which may also be made co throughout the whole row. Either this last method is ado a long second trough is added into which all the screens di and from which all the wet machines take their supply. T mits the cutting off of any screen for cleaning or repairs stopping the wet machine connected with it.

plates have been used for some time, and especially
s balsam is used, they become clogged and must be
s is usually done with a jet of steam or, if much gum-
piece of felt dipped in coal oil.

rlin Centrifugal Screen.

is a cut of the Baker & Sherlin's Centrifugal Screen,
presents it with part of the casing taken off, and figure
s the principle on which it works. As seen in this last
sists of an outer cylinder or casing *A*, of a cylindrical

Fig. 28. Centrifugal Screen.

late *B* perforated with small round holes, of vanes *V*,
C perforated at different plates with large holes, and
vertical shaft *S* on which the vanes are fastened.
admitted from pipe *F*, to which it has been pumped
de of cylinder *C*; the vanes revolving at a high speed
rifugal pump (hence its name) and cause the pulp to
it then passes through the large holes in *C*, which
ibute it evenly and is forced against the screen cylin-
the desirable part, i.e., that of a certain size and
es through and falls in *H* and the undesirable part,
e chips and splinters, remains inside and falls in *K*;

the good pulp passes from *H* into the distributing trough ab
wet machines, while the remainder passes from *K* into a
tank or a dumping place.

The holes in *B* are round and, therefore, quite differen
those in the plates of the vibrating type, and moreover, in th
the fibres must pass through them more or less end first.
ever, the screening action seems to depend, to a certain ext
a coating, as thick as the distance from the end of the vanes

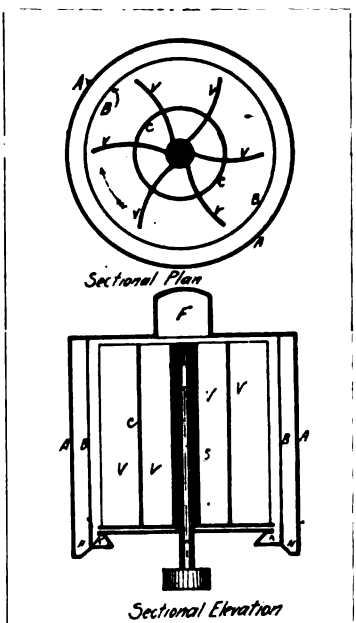


Fig. 35.

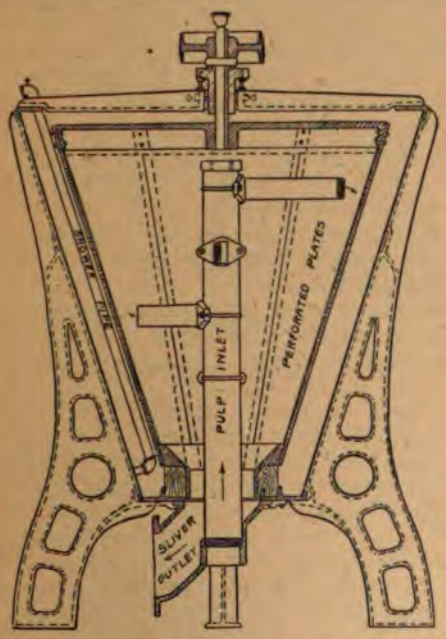
cylinder *B* will permit. which consists of coarse material co
against the inside of the plate *B*, through which coating t
must pass before reaching the holes in the plate.

Therefore, the screening action of this type is more
i.e., not so well defined nor so easily conceived as in the
the vibrating type, and hence can be judged by results onl
claim that one of these centrifugal screens will do the wor
many as 10 of the vibrating type; that it requires much less
and largely reduces the waste. On the contrary, others wo
use them because, as they say, they injure the felting powe
pulp, which they render mealy or short by breaking the lon

forcing them through a mass of chips and splinters. one of the many differences of opinion between manu- the pulp industry.

otary Screen.

reen is gaining favor with many Canadian manufac- leserves mention here. Figure 31 represents a vertical ugh it.



THE MOORE ROTARY SCREEN

Fig. 31. Section of Moore Rotary Screen.

ole screen stands about 9½ ft. high and, with the ex- the wood step, which steadies the bottom end of the ates and supports part of its weight, is made entirely of screen plates are of brass, made in sections, perforated .085 of an inch in diameter (smaller or larger at the e purchaser), and are secured to the steel frame by s.

The stock enters the screen at the bottom by mean pipe rising straight up at the centre of the screen and is d against the screen plates by means of four or more smal which radiate from the centre pipe in different direction the Baker & Sherlin Screen, the screen plates, and not t pipes and vanes, revolve in this machine, and usually a of 60 to 70 R.P.M. This produces a centrifugal force, gether with the force with which the stock is discharge the radial pipes, carries the desirable pulp through the ho the coarser material remains inside and gradually falls do sliver outlet.

The outside of the plates is kept constantly clean of a brass shower pipe; a larger capacity being then affor screened stock comes out through the pipe shown at th figure 31, and the slivers by the elbow at the bottom.

The plates are driven by a pulley on the top of the and are carried by a roller bearing of hardened tool ste contains 14 one-inch steel balls.

Like the Baker & Sherlin Screen the screening is don round holes, and most of what has been said regardi apply to the Moore Screen.

The manufacturers claim an output of five tons of p hours, with an expenditure of three horse power.

Most of the screens have a capacity of 20 to 25 to hours.

Wet Machines.

Theoretically, when the pulp has been screened the cal process of extracting and preparing fibres from wood and the product is ready for the paper mill. This is ac case when the pulp is employed immediately for the prod paper or cardboard, which some of our Canadian mills ture, but the large bulk is produced for exportation and, has to be put into convenient form for handling and shi

The wet machines are used to extract the pulp from which holds it in suspension, and to turn it into sheet taining a conveniently low percentage of water. First, a vat *A* into which the pulp is admitted from the scree the cylinder *B*, partly submerged, is a frame work cov very closely woven brass wire cloth, which allows the pass through while the pulp it contains adheres to it surface; the couch roll *C* presses the felt *D* against the *B*, causing it to take up all the pulp adhering to the cylin ing the wire cloth comparatively clean; the loaded felt th over roller *E* which guides its direction, over suction draws out part of the water in the pulp through the felt, ler *G* and between the press rolls *H* and *K*; the latter

water and the pulp gathers around the upper roll *H*. w unloaded, passes over stretch roll *L*, over roll *M*, is ater *N*, washed by sprinkler *P*, passes over guiding *R*, between the rolls *S* and *T*, which press out the water over roll *V* and again over cylinder *B*, taking a fresh and so forth continuously.

A is made of ordinary pine, is water tight and pro- outlet pipes, etc. The cylinder cloth must be of very tion so that no pulp will pass through the meshes nor too strongly; the ends of the cloth should be sewn not soldered as is sometimes done, because, at such

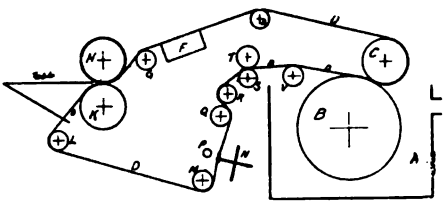


Fig. 37. Sectional elevation of Wet Screen.

onnection, water will not pass through, hence no pulp o that part of the cylinder and a gash across the sheet result with each revolution, thus decreasing the capa- achine. The couch roll *C* is usually made of cast iron over with soft India rubber, which facilitates the re- pulp from the cylinder *B* by the felt. The felt *D* is t 26 ft. long and 72 inches wide and is woven, in a adless form, of the best wool. Grey Canadian wool is for the work and gives as good, if not a better ser- . Most of the rolls are made of wood with the excep- oll *K*.

e is taken that the collecting roll *H*, which is formed piece of hardwood, is made perfectly true and is never y, so that the surface will not be cracked nor split. box is covered with a perforated plate, and as the felt the water is sucked down; some advocate that this should be connected with the draft tubes of the tur- of suction pumps, but the disturbance and loss of y caused exceeds that involved in the operation of ny mills prefer doing without suction boxes on the , leaving the work of driving out the water from the o the press rolls and partly to the hydraulic presses;

they claim that suction boxes wear out the felts much which seems to be reasonable, and it is a question whet produce a drier pulp. The press rolls are tightened tog means of a spring and hand wheel at both ends of the c roll *H* except in the case of that newly designed by the Machine Co., of Sherbrooke, Que., where water pressure connected to lever arms at both sides of the machine are do this work, this improvement insuring a more evenly di pressure between the two rolls, and therefore a more sheet. When a sufficient thickness of separate sheets of p gathered on the collecting roll *H*, the attendant cuts th with a "doctor" or knife, or, by means of a pointed stick wood which he passes quickly across under the sheets, w lower end is grasped and the roll allowed to complete its tion, the sheet falls on the table in front of the machine, is folded and sent to the hydraulic presses. The guide made of wood, on which a certain thickness of cloth is a spiral form, and by means of a conveniently placed han can be moved by the attendant to one side or the other, th ing the travelling felt in a proper direction. The beat made of four arms attached to a revolving shaft, and with water from the perforated pipe *P* cleans the felt from purities. The press rolls *S* and *T* are of cast iron and are together by screws; they squeeze the water out of the fe it takes a fresh load of pulp from the cylinder *B*. The the machine is of ordinary cast iron.

The capacity of an ordinary grey Canadian felt 72 incl is an average of five tons dry per 24 hours, with a speed 50 ft. per minute; when new it will carry more than whe worn out. These felts last from four to eight weeks, acco the treatment they receive.

If resinous balsam is used, the capacity of the ma much lowered, as the resultant clogging of the cylinder an irregular layer which the gummed felt will not pick up The cleaning is done as in the case of the screens by st coal oil.

Handling and Pressing.—

The sheet of pulp from the press roll, usually 1-8 to 1- inch in thickness, is folded on the wet machine table so th are no edges showing on the outside and ends, the fin being about 24 by 16 inches in size when a 72-inch wet ma employed.

This pulp contains about 65 per cent. or so of water d on the use or disuse of a suction box and on the pressure the press rolls. As the cost of shipping such a combinati

ater and 35 per cent. of pulp would be uneconomical
ases prohibitive, the percentage of water is reduced
ydraulic presses.
g folded the sheets are put on a truck specially con-
he purpose and, between each one or two folded
aterial as old felt or wire netting is inserted; the
is to facilitate the removal of the water when pres-
l. Some mills use wire netting only, but if this is
he pulp is liable to become spotted with rust, which
ch its value.
will not serve the purpose quite as well as a com-
th felt and wire netting, in which case a piece of
l between each sheet and a piece of wire netting
ieces of felt every three or four sheets. When the
l it is rolled to the presses.
is constructed with such a distance between the
hen the ram or platen of the press rises it is borne
ad of pulp, which is pressed without any injury to
s dispensing with unloading it.
press is of very heavy construction, the lower
iron having a brass lined cylinder, the piston and
e of steel, while the top piece and the platen are of
top piece is supported and kept in place by means
steel rods with screw and nuts at both ends.
ire used is from 1,500 to 5,000 pds. per square inch,
d by triplex pressure pumps of usual design. In
the platen of the press more rapidly up before it
s and down after pressing the cylinder is usually
low pressure pump, or the discharge from the bot-
linder may be let into the air, allowing the platen
ater out by its own weight.
ntage of water in the pulp after pressing, is usually
This varies sometimes from 45 to 55 per cent., depend-
essure applied and on the felting between the sheets,
practical extent on whether a suction box and very
between press rolls have been used in the wet

t of the presses is to get that percentage of water
sible, and their practical limit is reached when the
about 45 per cent. of water. To reduce this percen-
ethods with heat as an agency must be employed;
considered later.

g pressed, the pulp has to be baled into bundles
hipment. From the presses the trucks are rolled to
a sufficient number of sheets are weighed to form

a standard uniform weight of dry or wet pulp. This
weight or amount of pulp is then removed to a press.
sists of cast iron top and bottom, held together by f
rods; the pressing is accomplished by means of two kne
out or drawn in by a screw and sprocket wheel dri
chain, and the driving is so arranged, that when a certain
is applied the driving pulley falls out of gear and auto
stops pressing. When the pulp is placed in this press,
three laths are laid under and on top of it, and while
to pressure, the whole is tied by means of four or fi
inserted in grooves at the top of the bottom casting an
bottom of the follower. Pressure is then relieved and
is ready for shipment. Sometimes a wrapper is used,
often found more expensive than the loss of pulp occurring
If there is a chemical pulp mill in connection, a sheet
this process will be tough and answer the purpose very
at a small cost.

Tests.

There are two kinds of tests, for quality and for perce
water.

For testing the quality of the pulp at the mills, the f
methods are largely used: a glance at the sheet from
machine with a strong magnifying glass will tell th
whether the pulp is too coarse or too short; again, as t
1-8 or 1-10 of an inch thick issues from the wet machine
the hydraulic press, a piece may be torn off and folded twi
cracks or splits appear after this operation the pulp is co
good. Again, a thin sheet when held to the light should no
too large splinters or chips. There are many other suc
tests that may be made and are employed by different m
turers.

The tests for determining the quantity of water in the
performed by taking samples through different parts of t
and weighing them immediately, and then again after th
been dried by heat; the difference in weight gives the pe
of water in the pulp. This is a very delicate operation,
which requires skill and judgment.

The percentage of water in a bale differs at variou
throughout the bale, being, immediately after pressing, gr
the edges than in the centre. The percentage also varies co
from the time the bale is pressed until it is used at th
mill, due to the drying up of the sides. The weight also
from loss of pulp in manipulation and handling.

These variations, which are the cause of constant d

n purchaser and seller, have originated a movement wards standardizing methods of testing.
satisfactory method of determining a weight agree- purchaser and seller, is for both parties to determine e of water in the bales when it is most uniform, i.e., es from the hydraulic press.

oned before, this mechanical process transforms into ly all the solid substance of the wood except the y loss occurring in the splinters that pass through which are too large to pass through the screen holes.
f green spruce weighing 4,400 lbs. will weigh about being barked; this will produce on the average 1,900 cent. of the weight of the green wood; the remain- t. being the water in the wood and the waste occur- the process. Such a cord of wood treated by the ite process would yield from 1,000 to 1,300 lbs. dry

Pulp.

seen that pulp when baled contains from 45 to 55 per , 50 per cent. being somewhat a standard in most this pulp has to be hauled only a short distance, this water is not a very serious difficulty as the freight mall and the pulp can be more easily reduced to a , but this is not the case when it has to be carried e.
ated near seaports, such as those in Quebec and the inces, can still afford to export 50 per cent. of water p, but such conditions are ruinous to those situated hence with longer railway transportation. This is y some United States paper mills can import their d barked instead of moving the pulp mills to the ing their pulp to the paper mills.
also seen that the percentage of water or pulp is a ute, and that we must use heat to reduce it below

e largest mills in Canada has been turning out ried pulp with a machine whose principle is illus- e 38. The first part is the same as an ordinary wet felt, press rolls, etc., but the pulp instead of col- one of the press rolls is taken up by another felt a roll and a large drum heated by steam, around

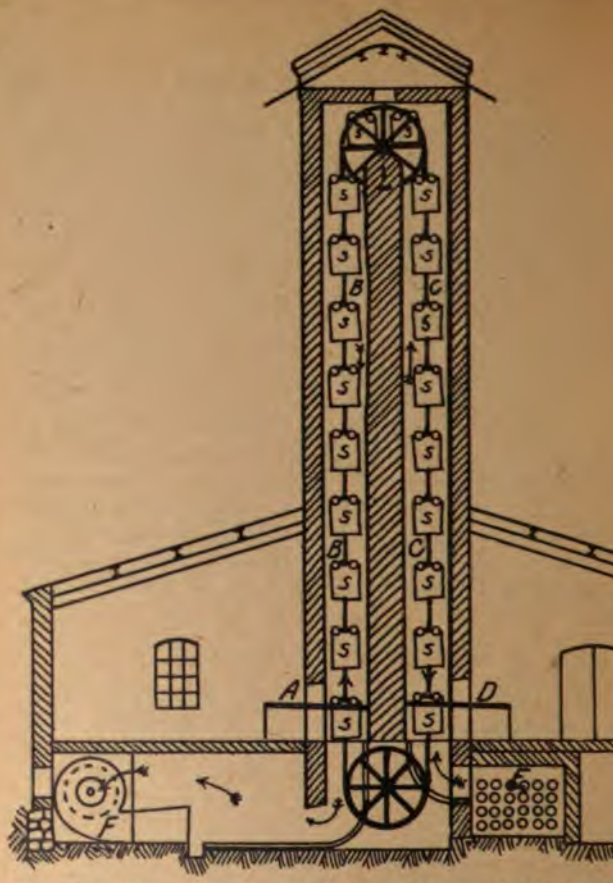


Fig. 39. Tower for Drying Pulp. S, pulp sheet; P, p

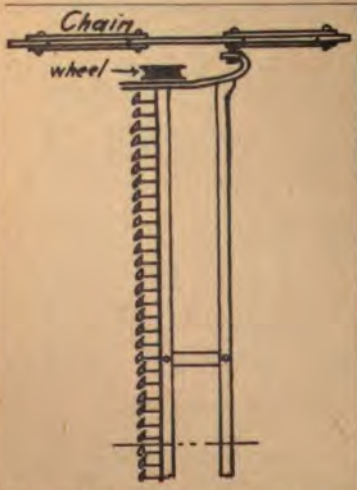
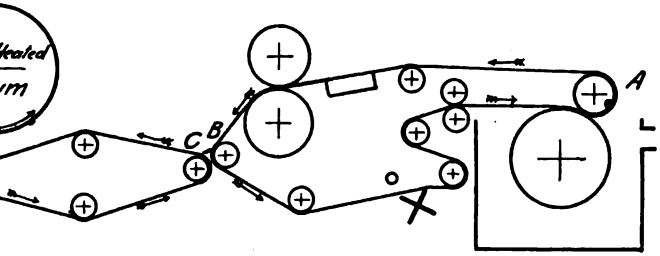


Fig. 40. Sheet wagon or frame.

Fig. 41. Cl

the sheet of pulp from the felt is made to pass and on a spindle at the other side ready for shipment.
hine is simple and works economically, but the diffi-
eep that single drum at such a temperature that lit pulp without burning or scorching it.
nt this tendency to scorching in a single drum, ma-
several drying drums have been tried without very

d, we may say that heretofore most of the mechanical
rying pulp have not been a success, and that there
n for improvement.



onal elevation of Dry Pulp Machine. From A to B is same
nary wet machine. From C to B is the drying part.

method giving perfect results is by means of hot air,
pulp sheets are exposed, and this method is not em-
merica. Many mills in Scandinavia have adopted it
it by so doing. Its principle is this: Pulp sheets are
ks and made to pass through a chamber, at one end
t air is admitted, and after being exposed for some
hot air they come out dried. This is achieved by two
e *tower* and the *chamber* processes.
represents the *tower* process. The pulp sheets are
cks represented in figures 40 and 41 until the rack
each end is connected to a long linked chain at *A*,
it goes up *B*, comes down *C* and goes out at *D* dry.
l at *E*, goes up *C*, down *B*, to a fan *F* and back to
s reheated.
nber process is practically the same; the only differ-
the fact that the chains carrying the racks move hori-
ead of vertically.
reason (which indeed is an important one) why these
e not used on this continent, is the great cost involved
allation and operation; not only is a large building

of special construction required, but during the process, dividual sheet of pulp must be handled several times.

Generally, when the pulp is not very well wrapped not much advantage in drying it over about 90 per cent. it will absorb enough water from the atmosphere to re percentage when exposed.

Hughes' Process.

The Rivière du Loup Pulp Co., of Fraserville, Que., h stituted, in their recently built pulp mill, a new proces the Hughes Process) for preparing the pulp for shipment.

In this process the pulp is ground and screened s ordinary way, but from the screen the pulp passes over form of "slush machine," which extracts the greater pa water, leaving the pulp of about the consistency of porri this form it is pumped directly into the *Hughes Hydrau Machines*, which consist of a compression chamber divi four spaces by drainer plates covered with wire cloth, compression chamber a hydraulic cylinder is attached, any desired pressure can be exerted.

The pulp is admitted to this compression chamber pressure is applied, which extracts the water through th plates, and the finished product is delivered in the form 20″ by 26″ by ¾″ thick.

As seen above, the ordinary wet machine and hydrau are replaced by the Hughes Press, with the result that sheet of pulp porous and spongy is produced as compare matted or interlaced thin sheet obtained by the ordinary

The percentage of water in both sheets should be mately the same if the same pressure has been applied, former is appreciably more readily reduced to a liquid ma in the beating machines of a paper mill.

The new press, requiring as it does little more power ordinary hydraulic press, has this in its favor, that it with wet machines together with the power necessary to them, while the amount of floor space thus occupied is sa

If these presses prove as successful in their operati anticipated, their invention will mark a distinct advance pulp industry.

Uses of Mechanical Wood Pulp.

The chief use of mechanical wood pulp is, of course vide a paper making material. It has many other use yearly increase in number and importance, but at presen be said to be all practically employed in the making of p cardboard.

We have now examined the essential properties of

ces from which it is derived, and the different pro-
ch it is obtained from wood; we have also seen the
ween a chemical and a mechanical pulp, and why
aturally inferior in quality. This is why mechanical
es not produce a paper of good consistency; it is for
at it goes only as a percentage in the manufacture

s ago it was thought that 50 per cent. of mechani-
s much as could be allowed in the cheapest kind of
account of more improved methods of manufacturing
and pulp, as much as 85 per cent. and even 90 per
used in some of the "News" paper. This is the
ximum, while the percentage below that may be any-
zero, according to the quality of the paper pro-

largely used for cardboard and wrapping paper,
entage is again greatly varied.
paper and cardboard, wood pulp is now employed in
re of a great number of articles of common use,
tubs, trunks, cases, barrels, etc. Complete houses
wheels have been made of it.

MANUFACTURE OF PAPER.

out our system of treating this subject, it is neces-
short description of the manufacture of paper.
pulp is brought in bales to the paper mill it is first
gether with a proper percentage of other kinds of
er into a beating machine where all the particles are
each other; from there it is sent to a tank or to a
the desired amount of loading or sizing material,
or talc is added, and the whole is bleached or
case may be; this is then diluted with a large
ter so as to form a very fluid substance. In this
itted to a Fourdrinier machine, where the water con-
p is allowed to flow to a certain depth on a travelling
ich retains the pulp and allows the water to pass
vire sheet then passes over suction boxes and delivers
ree successive felts on which it is pressed; from the
heet, now of a certain consistency, passes around a
g drums and cylinders, through a calendar, which
r a required glaze and finally the sheet is rolled or
se.

OST AND VALUE OF MECHANICAL PULP.

of producing a ton of mechanical wood pulp in
ing the cost of wood to be about $4.00 per cord, is
$9.00 under ordinary favorable circumstances. The
and what influences the most its value at the mill,

is its transportation to markets, in our case, Great Br
the United States principally.

The price paid in Great Britain is sometimes as low
to $15.00, and as high as $25.00 to $30.00 per ton, dry,
on general rules of supply and demand.

In United States, last year, the price varied from
$25.00 per ton, dry, delivered. Their import duty is a
per ton.

It is generally considered that mechanical wood pulp
a ton in United States or Great Britain, could be man
with profit in most parts of Eastern Canada.

Statistics and Remarks.

The Statistical Year Book of Canada shows that d
calendar year 1902, the wood pulp industry was carried
mills, four of which manufactured soda pulp, nine sulphit
mechanical, and four both chemical and mechanical.

These mills had an output of 240,989 tons; of this qua
210 tons were mechanical pulp, 76,735 tons sulphite, and
soda; having a total value of $4,383,182.

In 1881 the census returns show that there were i
five pulp mills, with a total output valued at $63,000. T
that the growth of this industry in the last 20 years has
siderable.

The customs returns for the calendar year 1902,
during that year the export of pulp amounted to $2,511,6
$1 871,518 or 43 per cent. for home use. Of this export,
tain took $976,172; United States, $1,518,319, and other
$17,333.

Our export to Great Britain was about 8½ per ce
needs and, therefore, all our mills could not supply thei

Owing to the duty on pulp imported into the United
the facilities afforded them in securing wood for man
pulp in their own mills, the Americans are stripping o
in the Provinces of Quebec, New Brunswick and No
About one-half of the pulp wood used in the United Sta
rived from Canada, as their home supply is becoming s
at the present rate of consumption would be exhausted
century if they could not import wood from here.

It is a well-known fact that we have the largest
forests in the world, and this added to our large amount
able water power, makes a perfect combination as a
wealth. According to Mr. J. C. Langelier, of Quebec,
supply the world with 1,500,000 tons of pulp annually for
with our present forests.

is wealth has been little taken care of, as little been passed to prevent its waste and regulate ns; but the Canadian people are becoming alive to of reforestration and to the necessity of preserving y strict regulations regarding the cutting of the

hoped that in the near future the science of forestry here with the same efficacy it has shown in some n countries.

een that great pains are taken to dry the pulp for also that if paper and cardboard were made directly dispense with wet machines and presses. Hence the laws of economics will become more adjusted, al and labor will be saved by making paper and etly at our pulp mills; then Canada will surely be- est paper producing country in the world.

amount of the information contained in this paper, ndebted to the following:—A paper on the Process ng Mechanical Wood Pulp, read before the En- ty of the School of Practical Science, Toronto, in A. Hare "99"; to catalogues and descriptions from irms: Jenckes Machine Co., Sherbrooke, Que.; The ne Works Co., Brantford, Ont., and Carrier, Lainé Que., and to different articles published in the Cana- an and in the Pulp and Paper Magazine, both of

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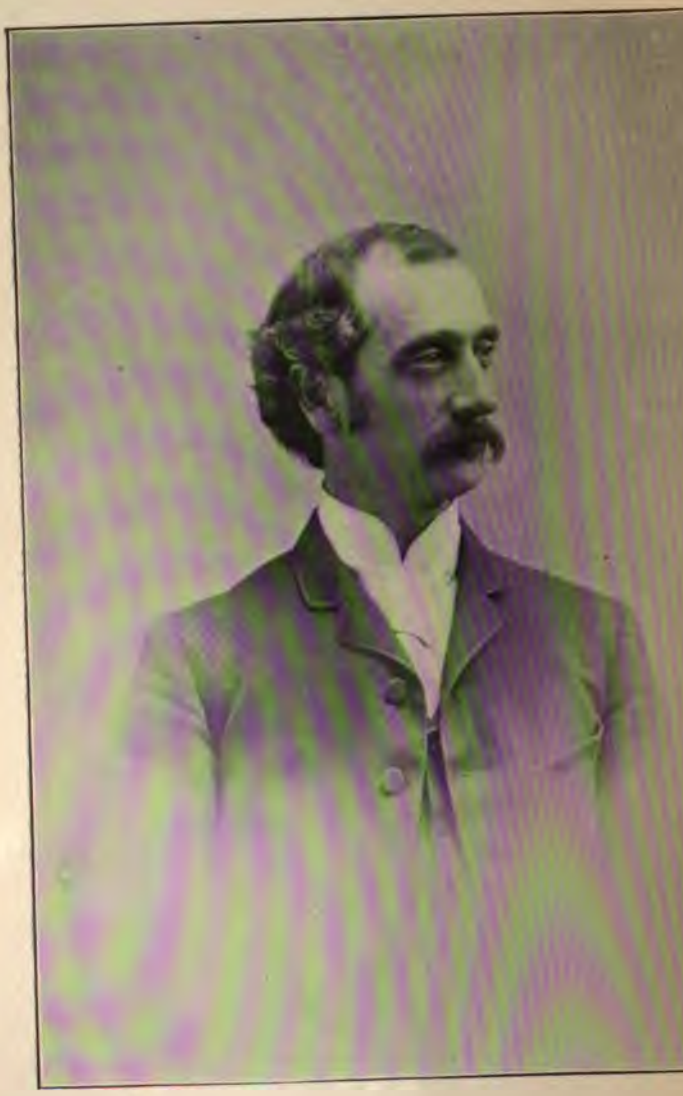

Ernest Marce

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of the

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VOL. XIX

1905

Montreal:
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INSTRUCTIONS FOR PREPARING PA

In writing papers, or discussions on papers,
person should be avoided.

They should be legibly written on foolscap
only, with a margin on the left side.

Illustrations, when necessary, should be dra
of tracing linen to as small a scale as is cons
ness. They should not be more than ten inch
no case should any one figure exceed this heigh
should be used, and all lines, lettering, etc., mu
tinct.

When necessary to illustrate a paper for
must be furnished. These must be bold, d
visible in detail for a distance of thirty feet.

Papers which have been read before other
been published, cannot be read at meetings of

All communications must be forwarded to t
Society from whom any further information r

The attention of Members is called to By-La

BUSINESS MEETING.

ess meeting of the Society was held on Thursday, h, 1905, Mr. W. McLea Walbank in the chair. The ion sale of periodicals was conducted by Mr. J. M.

MECHANICAL SECTION.

President—PHELPS JOHNSON.
Vice-President—M. J. BUTLER.

ng was held Thursday, January 19th, 1905, Mr. Phelps the chair. The following paper was read:—

s.

ROPORTIONS AND DESIGN OF LOCOMOTIVE CROSSHEADS.

By W. F. DRYSDALE, S. Can. Soc. C. E.

motive crosshead is that block which connects the iston rod with the small end of the connecting rod, and ween guides, prevents undue strain being transmitted nnection. It must be so simple as to be easily handled repair, it must be strong enough to withstand a large ough usage due to accident rather than piston thrust, must be so designed that little work is absorbed by it

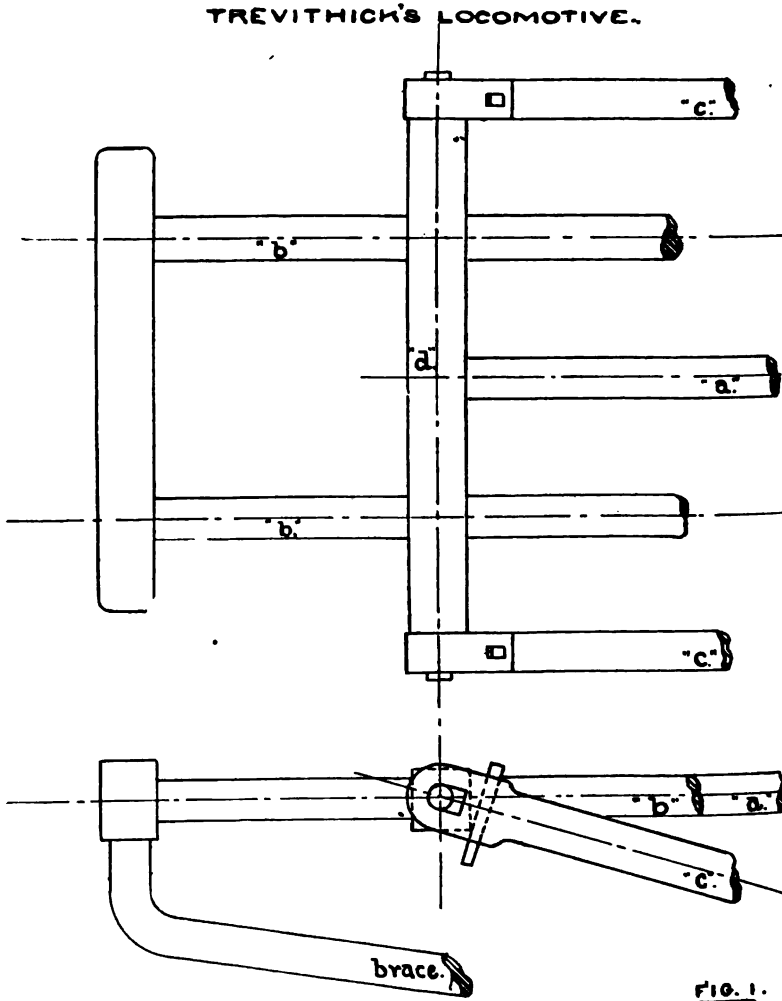
l endeavour to study its development from its earliest standard types as now used on modern locomotives.

Trevithick's locomotive of 1803 had no crosshead, in odied the three main features of one, namely, piston on, main rod connection, and a common guide for both. a plan and side elevation of this arrangement where iston rod, "c, c" the connecting rods fastened to the d guided by the bars "b, b."

A) shows a modification of the above, in which only one od was used.

Stevenson's "Rocket," 1829, was the first locomotive to use a crosshead. This consisted of a small block running between two guides; a short connecting rod, which must have caused great ver-

PISTON AND CONNECTING ROD MOTION
TREVITHICK'S LOCOMOTIVE.



Sketched from model in Field Museum. Chicago

FIG. 1.

tical thrusts on the guide bars, was a noticeable feature. In the early thirties American designers adopted a crosshead which was guided top and bottom by round bars. (fig. 2.) Lack of ready ad-

o wear, and weakness were chief points in this design. the two-bar crosshead as seen in fig. 3. The guide bars of boiler iron, a cast iron head being used.

shows a crosshead used on the "James," built by Wm.

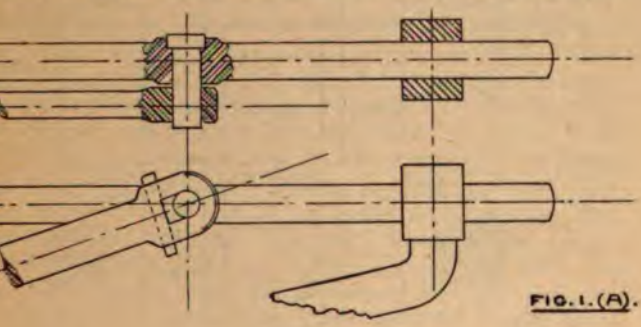


FIG. 1. (A).

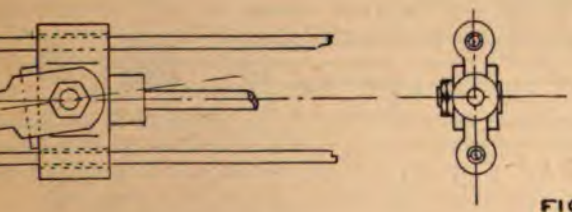
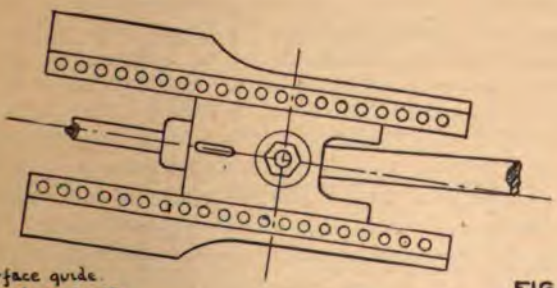


FIG. 2.



surface guide.
st mogul ever built.
Harrison. 1839.

FIG. 3.

of New York, for the Baltimore and Ohio Ry. in 1832. s on the "Sandusky" built in 1837. Fig. 6 that on the the first locomotive to run into Chicago. In the early rican designers adopted the single bar type. Commencing

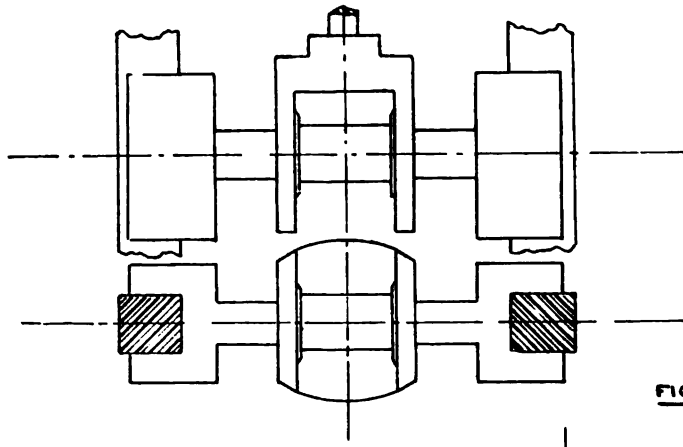


FIG. 4.

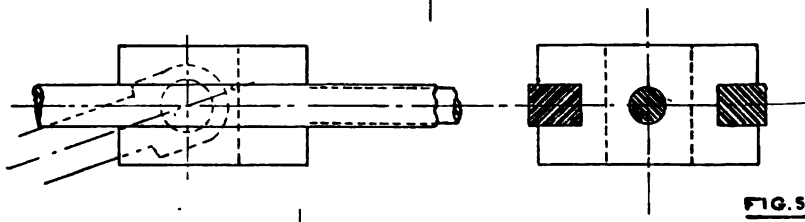


FIG. 5.

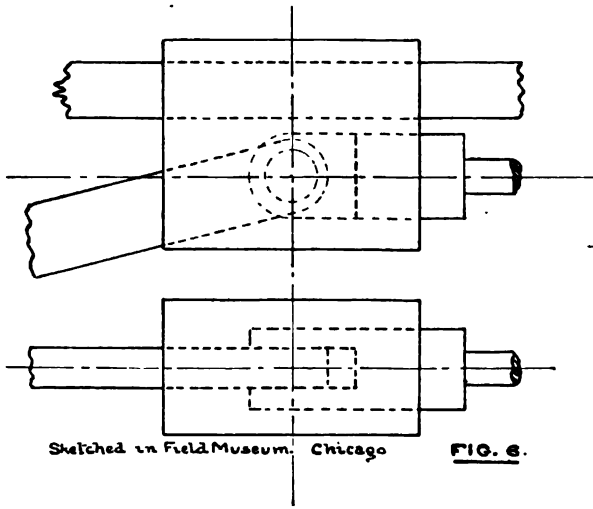


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FIG. 6.

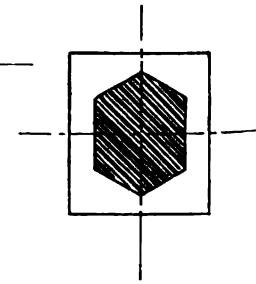


FIG. 7.

of section shown in fig. 7, they finally adopted the tangular shape (fig. 15.). We may here note that the ners made no attempt to transmit their power through motion, and we shall presently see that they were justi-ificing force for the sake of simplicity of construction.

ORMS.

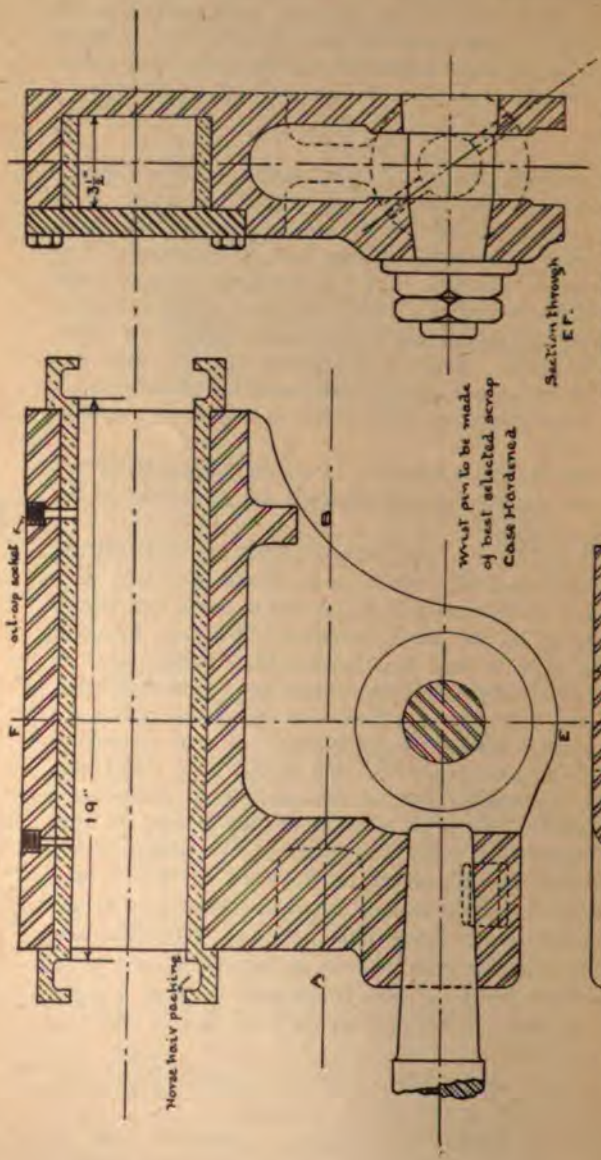
otive crossheads, the world over, belong to three classes: e two-bar, the four-bar, and the single bar types. It is here are many heads that do not come under the above on, but they are special designs and not standard. The pe, as seen in figs 8, 9, 10, 11, is the most common head e American Continent. The guide bars are equi-distant ttom from the piston rod and are central with the verti-f the cylinders. The pin is always separate, and lies centre of the slipper block. The heads are usually made l with brass shoes top and bottom, and steel pin, as seen

iron type (fig. 9) is common in which the socket is re- ribs cast between it and the shoe supports—see "a, a" re.

sual on this type to use brass liners on the sliding ith a cast iron flange bolted on as shown at "b b." This as simple as that seen in fig. 8, and is being supplanted er on many of the large American Railway Systems. ar type, seen in figs. 13, 14, and 16, consists of two ch run on either side of the piston and connecting rods, ned in one casting which forms connection for piston rod e pin around which the connecting rod end oscillates. is made of good wheel cast iron or cast steel. Although ad pins are usually part of the casting, on some roads ns are used. The weak features of this design are that es not always lie under the centre of the slipper block, ven distribution of pressure on it; when the pin is cast, s a difficult operation to machine it and keep it in order; liding surfaces are more difficult to deal with than two. e in cast iron this type is weak at points "a, a," "b, b" To prevent breaking some roads have ordered wrought to be shrunk around the flanges next to the inside of

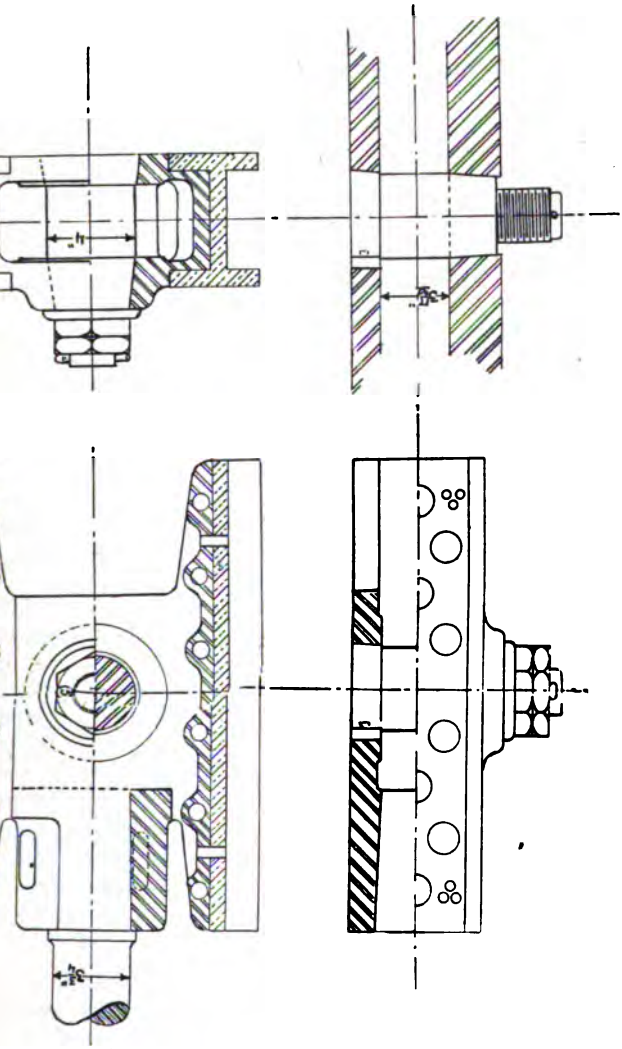
ide bars are made of wrought iron, case-hardened, and h emery wheel to the proper surface.

shead which belongs to this class is seen in fig. 14, esents the head used on the Vauclain compound made by of Philadelphia. In this the high and low pressure



CAST STEEL CROSSHEAD

are connected on each side to a single head. The four
ces are situated horizontally outside and vertically be-
iston rods. An open hearth steel casting with block tin,



CAST STEEL CROSSHEAD, G. T. RY. SYSTEM.
20 x 26 Engines and Rich. Comp.

lining, for all bearing surfaces, and a separate steel
principal features. It is a well designed crosshead and
ittle trouble on the road.

The single-bar type:—Fig. 15 shows a crosshead w
used successfully for many years on roads in the U
In it the crosshead embraces a single guide bar, the
surface being lubricated by means of oil holes drilled
bar. It is a strong head and gives a large amount of
the connecting rod, and other parts, besides it is si
struction and easily lined up.

Fig. 18 represents a form of crosshead where bo
are placed above the centre line of the piston rod.
carries the pin, whose centre is in direct line with
piston rod centres. "A" (see fig.) is a crosshead fillin
is bolted between the two checks "b" and "c" of t
This is a simple crosshead to set up, all that is neces
clamp up both bars to embrace the filling piece, raise
up, and bolt it in position. This crosshead is used w
ing wheels come opposite the slide bars, as in mog
dation engines. One weak feature of this design is t
to adjust the sliding surfaces for wear. Fig. 11 shows
by Baldwins on their Vauclain compounds. It has
designed to give clearance for a short connecting rod.

It may be interesting, at this point, to glance a
designs used on British locomotives. In Fig. 16 we
which is in common use on inside and outside conn
It belongs to the four-bar type; a wrought iron cross
pin which acts as journal for the forked end of the c
"a, a" and the cast iron slide blocks "b, c."

Brass liners are sometimes inserted between th
blocks and guides to reduce friction. In all of its
it is similar to the American four-bar type, as alrea
Fig. 17 illustrates a head in which the piston rod a
are forged in one piece, and the whole is free to turn
hardened wrought iron journal, which is keyed to t
rod, except for the constraint of the guide bars. Thi
sive design, is weak in support, and would withsta
twist. Fig's 19 and 20 show by end views the chief f
struction of three-bar types, which are in use to-day.
bars are shown in section.

COMPARISON OF PARTS.

Strength of Guide Bars.—All guide bars shou
strong enough to withstand excessive shocks such a
be subjected to if a rod were knocking at its brasses
other of the extra destructive effects due to an engine
a rough track

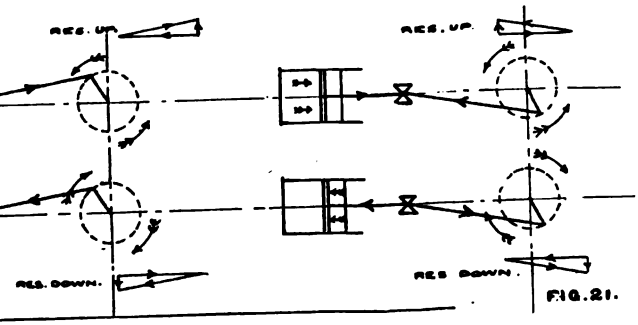
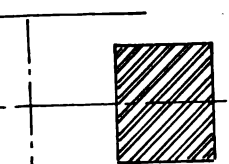


FIG. 21.

TABLE I.

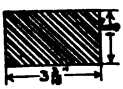
MORSE MOGUL
G.T.Ry. System.
20"x26"x63" DRIVERS.

f — 6000#/□" y — 2½".
m — 66500"#.
ax. bending moment
ixed ends, take $m = \frac{Wl}{8}$
nce acting at centre.



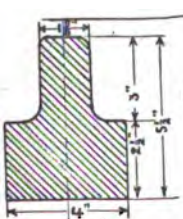
N Vaudain Compound.

1.33 for each bar
y — 2"
= 121400"#
#



BALDWIN
14"x25" SWITCH. ENG.

length of slide bar (l)	47 5/8"
moment of inertia (I)	11.41
safe stress per sq in. (f.)	6000#
neutral axis to outside (y)	13/16"
moment of resistance (M.)	84200 in. lbs.
max. moment on bar (m.)	17275 in. lbs.



G.T.Ry. Mogul.
18"x24" STROKE.

l — 55 3/8" I — 33.54 f — 3000#/□"
y — 2¼" M — 44,720"#. m — 44200"#.
Cast Iron bars break frequently, but give excellent satisfaction while running

STRENGTH OF GUIDE BARS.

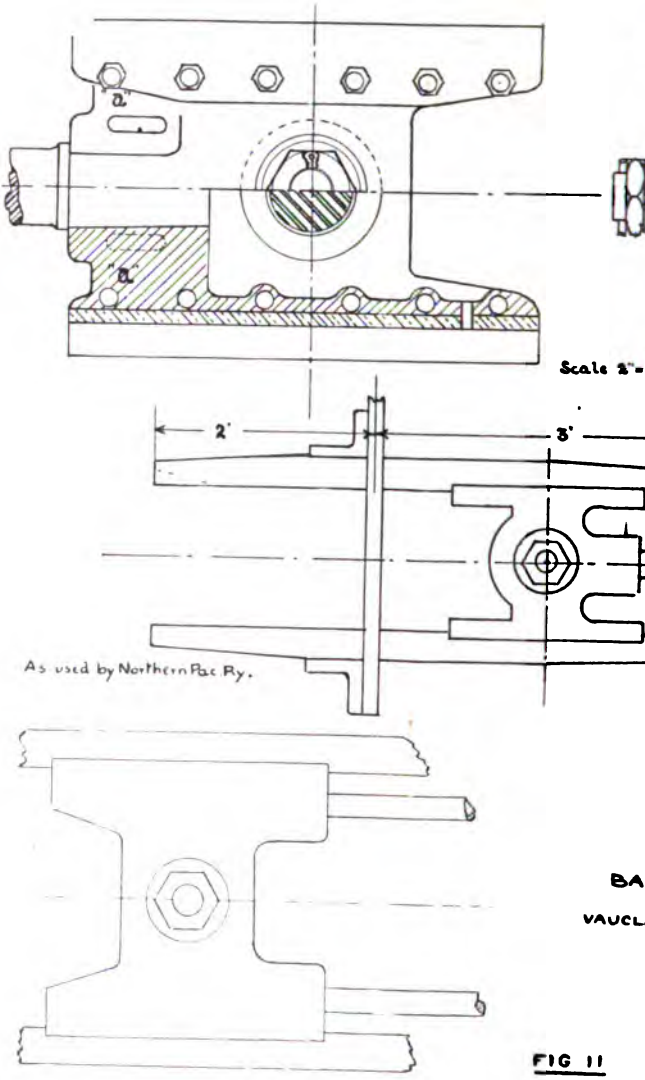


FIG 11

ides are always subjected to great vertical strains. To
e they must be strongly bolted at the front end to the
der head, and at the back end to the guide yoke (see fig.
n turn is bolted to the engine frame, and usually also to

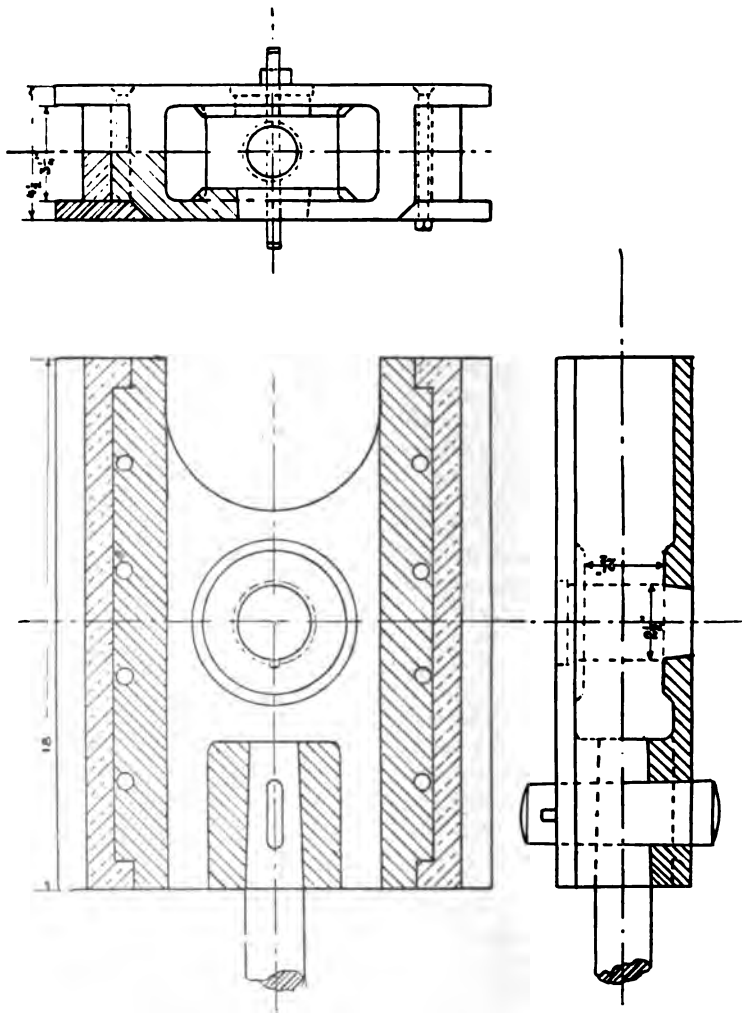
ction of the guide-bar is always greatest opposite the
he crosshead stroke, as this is the place where the max-
ard thrust takes place, and, since most bars are supported
, here the greatest bending moment is found. Guide bars
of steel, cast iron, and wrought iron. It is the opinion
ilroad men that the cast iron bar gives the best satisfac-
. The rubbed faces of these bars are often chilled in
rips to make them wear better. All wrought iron bars
rdened and ground.
better that the surface of the slipper blocks should
e the guide bars: to ensure this the slipper blocks are
a softer metal than the guides are made of.
p bar must be made stronger than the bottom bar, for in
work the engine is running in forward gear more often
running backwards—now while in forward gear all pres-
on the top bar and vice versa—the reason that this is
adily be seen by examining fig 21. By taking the con-
d in two positions for each direction of motion, and re-
e forces and reactions which keep it in equilibrium, by
e of forces we can see that this statement is so. Of
here suppose that the centre of the cylinder comes in
with the crank pin centre; if this is not so, the statement
olutely correct.
10 we see a bar supported at a point two-fifths of its
n the end. This is a good feature, in that the bar re-
maximum thrusts close to its point of support.
ress on the guide bars is due to the pressure of the steam
ton, acting obliquely on the crank, and is greatest when
is at right angles to the connecting rod. We shall here
der the maximum thrust, and for simplicity, we will
he steam pressure constant throughout the stroke;
the weight of parts, inertia forces, and frictional loss in
nd gland. See fig. 24.
ax. when A. B. C. is a right angle. From similar tri-
ay readily be seen that

$$\frac{R}{nH} = S \quad \therefore \quad S = \frac{P}{n}$$

all by the above formula, knowing the values of P, n, and
inertia of the guide bar, etc., determine the relative re-
f four types of bar. See "Table I."

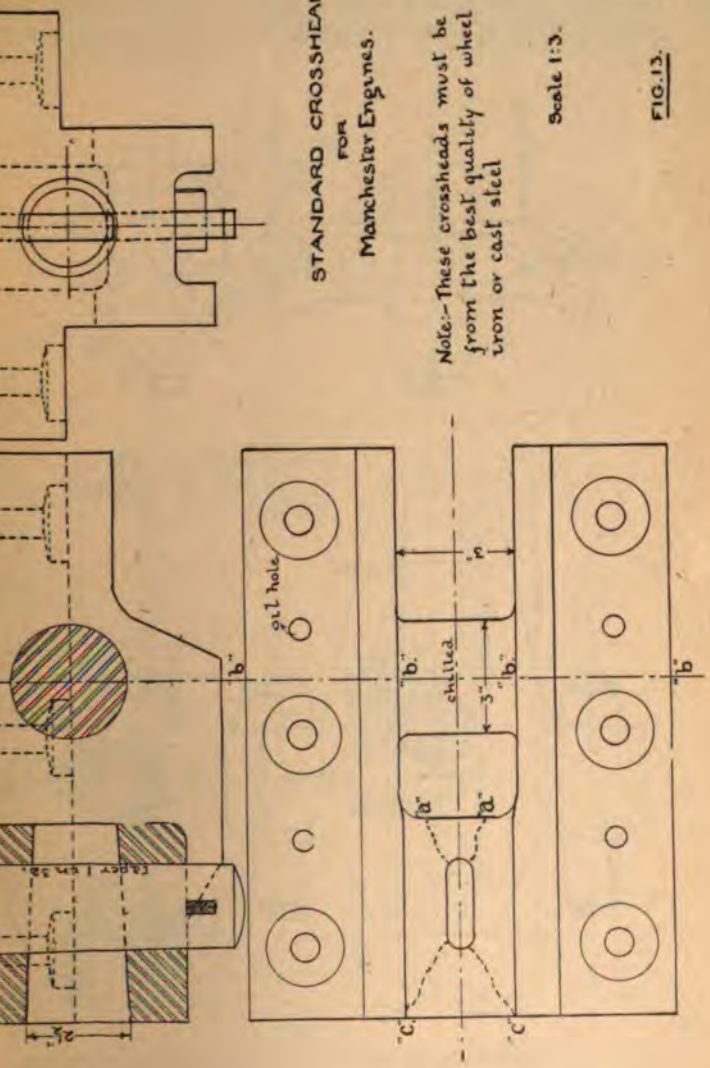
Clearance cuts, at the end of the guide bars (see "d d." fig. 18) are placed there to prevent the formation of a ridge at the point where the crosshead reverses, thus preventing. binding and

FIG 12.



CROSSHEAD, BALDWIN LOCO. 14 x 22 INCHES, SWITCHER.

throwing off any grease or dirt which the crosshead may have gathered.



STANDARD CROSSHEAD
FOR
Manchester Engines.

Note:- These crossheads must be from the best quality of wheel iron or cast steel

Scale 1:3.

FIG. 13.

FRICTION BETWEEN SLIPPER AND GUIDE.

Considering the fact that parallel motions are not used in locomotive construction, particularly in transmitting power from the cylinder to the driving wheel crank, we have to reckon with a considerable loss of power in friction, due to the resisting forces of con-

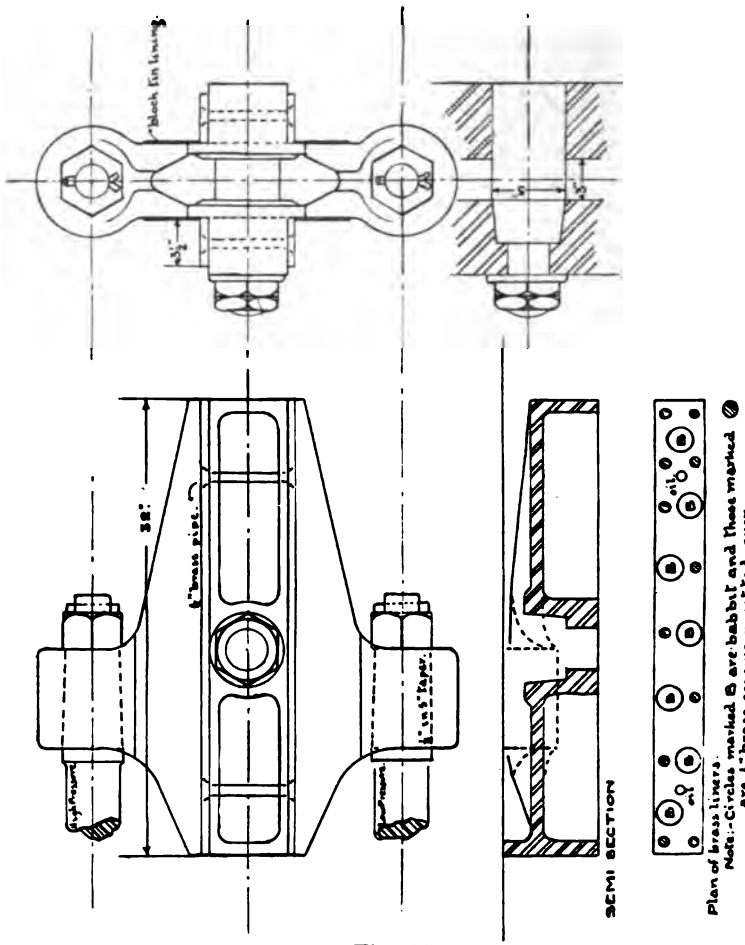


Fig. 14.

CROSSHEAD OF BALDWIN COMP. VAUCLAIN TYPE.

strained motion. It is the duty of the designer to so construct his parts that this loss may become a minimum. The frictional loss due to the weight of the reciprocating parts on the bars is neg-

ompared with that due to the upward and downward ed by the angularity of the connecting rod. To reduce must therefore lengthen our connecting rod and thereby ngularity. Again, the frictional loss may be reduced by rubbing surfaces made of, or lined with, some form of

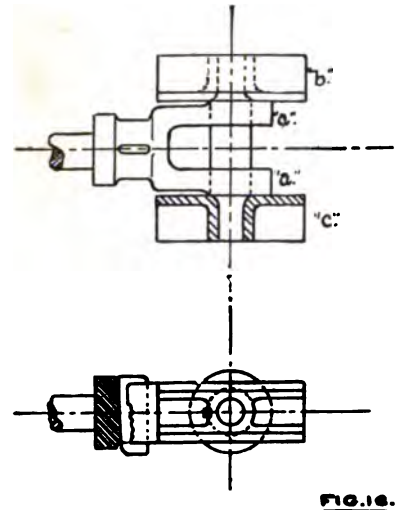


FIG. 16.

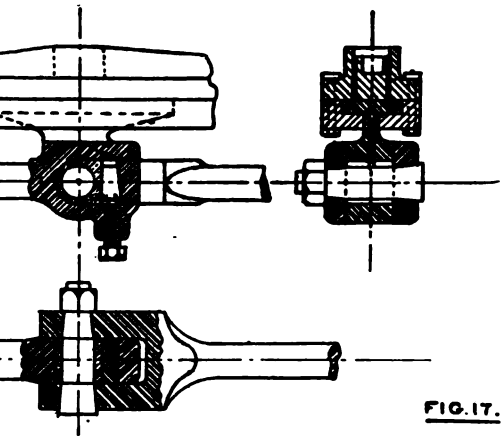
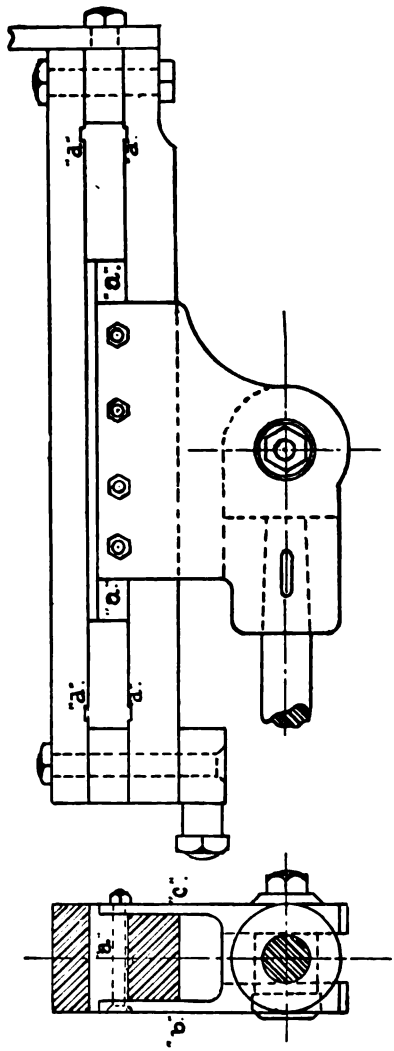


FIG. 17.

al material; also by taking care to have these surfaces well lubricated.

g the pressure on the sliding blocks, and their dimen- hall compare the intensities of pressure to which the

various materials used are subjected. In a preceding paragra. means of determining the maximum thrust on the guide bar. explained. Taking this value and dividing it by the area



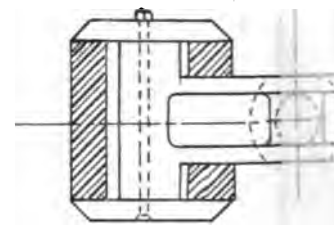


FIG. 20.

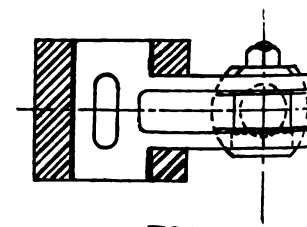


FIG. 19.

From sketches made in Roundhouse.

slipper block we arrive at the intensity of pressure. It is true that this intensity decreases at the ends of the stroke, and as the speed rises, but we are here dealing with the severest test it must under-

ll take place on starting, when the value of the co-
iction (u) is greatest. Knowing the amount of thrust
bar, and the value of "u" for rest, we can readily com-
unt of force required to move the crosshead from rest.
of intensity of pressure on guide bars, an authority
comotives having steel or case-hardened wrought iron
ssure is sometimes as high as 120 lbs. per sq. in. This
high, and will soon wear down the guides and cross-
'he pressure per square inch should not exceed 40 lbs."
the above with values seen in "Table II."
sure of oil or other lubricant between the rubbed sur-
o reduce the friction and lessen the heating.
le bar, slipper block, and crosshead casting must be of
ume to allow the heat to dissipate freely, or else it will
esult in "running hot."
to determine the starting effort, maintaining effort,
ower wasted in friction, a value of "u" for crosshead
necessary. All mechanical engineer's hand books con-
which are approximately true. Local conditions, such
erature of sliding surfaces, lubricant used, speed of
, have a great deal to do with these values.
to find the co-efficient for crosshead and guide as used
es now being bui't by the Grand Trunk Railway in
St. Charles Works, the writer resorted to the following
od:—A bottom guide bar was placed flat on the floor, a
ckle was fastened to one end of the bar, while the cross-
owed to lie freely on the level surface of the bar. The
ckle then gradually raised one end of the bar while the
ted as a pivot. This operation was performed slowly,
g constantly rapped with a copper hammer to prevent
il the angle of repose was reached and the crosshead
rest. The angle ϕ was determined by means of a
and protractor.

owing were the results:—

ntally determined.

	u.	Conditions.	Remarks.
ght	.1405	dry.	Atmospheric temp.
	.1317	oiled.	about 82° Fah.

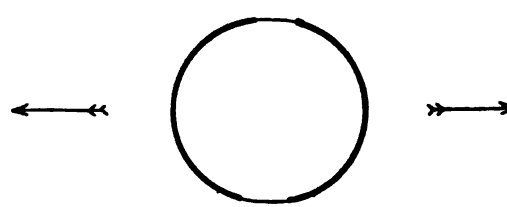
Jenkin and Ewing's results.

Surfaces.	u,	Conditions.
Cast Iron on Wrought Iron	.171	dry.
Steel on Brass.	.146	oiled.

DESIGN OF CROSSHEAD PIN.

The crosshead pin must be placed in a position where it will create no bending moment, and will distribute the vertical thrust equally over the slipper block. This being so, there only remains one place for it, and that is the intersection of the line through the cylinder and piston rod, and a line dropped vertically from the centre of the slipper block. Its position having been determined, it must be so dimensioned as to resist shear and bending moments on it as transmitted to the connecting rod; it must be of large enough diameter to reduce the intensity of pressure on it to within certain limits; and it must be short enough to allow for the side twist which is present at times on locomotives. It must always be of sufficient volume to absorb and conduct the heat of friction, and be so prepared as to give little trouble when running.

Crosshead pins are usually made of high grade steel or case-hardened wrought iron and sometimes, where the pin is part of the crosshead casting, of cast iron. They are made flat top and bottom to give clearance for the oscillations of the brass and to leave a bearing where the thrust comes. Thus:—



Locomotive wearing parts must be so designed that they can be readily adjusted to wear. In crosshead pins the wear is usually taken up by wedging the brass bushes together. Now, the greatest pressure comes on the front and back of the brasses; and as these are closed together the sides have to be eased off with file or scraper. This is the reason that pins are often made of elliptical snape, and the brasses are always eased off before being put into place.

owing the maximum thrust on the connecting rod, and the the surface bearing it, we can easily determinte the intenee "Table II."

TABLE 2.

A COMPARISON OF INTENSITIES

Class of Engine	Area of Single Sliding Surface.	Force "S"	Max. Intensity on Slipper	Area of Main rod Brass Contact.	Force "T"	Max. Intensity on Pin.
Baldwin 14"x22	54 □"	2590#	48#/□"	9.82 □"	25060#	2500#/□"
Kingston 18"x24"	90 □"	6560#	73#/□"	14.14 □"	63400#	4000#/□"
Baldwin 15"x20" Vauclain Comp	112 □"	8680#	77.5#/□"	23.57 □"	93600#	3900#/□"
Morse Mogul 20"x26" stroke.	120 □"	8950#	74.5#/□"	26.6 □"	78500#	3000#/□"

Forces "T" and "S" are maxima, the angle ABC being 90°. Force "T" = mP where m is a coefficient depending upon angular thrust & inertia of parts, and here taken as 1.25. When the rod, brasses receive their max. intensity of pressure, they are oscillating very slowly.

es of Design in Side and Vertical Twist.

iticism of the main features of the locomotive from a al standpoint generally results in the discovery of many

glaring malformations. The frames lack the necessary triangular brace, and there is apparently a looseness about the parts which, to the uninformed, betokens a serious lack of judgment and craftsmanship. But beware! Watching an engine as it "stands at ease" in railroad station or on roundhouse pit is a very different matter to watching it as it speeds along at 70 or 80 miles per hour—as it slackens up to leave a tangent track and turn on an 8° or 10° curve. Watch the bending of its parts, notice how nicely it hugs the rail, without a bind or buckle, riding as smoothly as can be; only now can one readily see the necessity of having this automaton made loose-jointed. Since locomotive crossheads, like all other parts, are subject to side and vertical twists there must be plenty of side and bottom clearance on their guides, and the bearings must have sufficient slack; besides both the pin and slipper block must not be made too long.

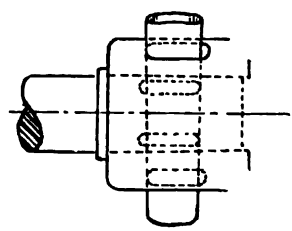


Fig. 22.

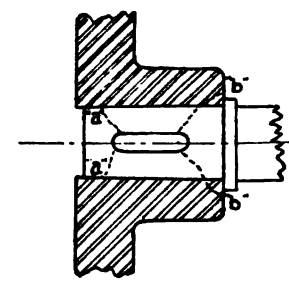
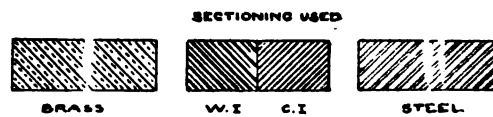


Fig. 23.



STRENGTH OF PISTON ROD CONNECTION.

There are two distinct ways of fastening the piston rod to the crosshead. Sometimes the rod end is so forged that it receives the pin on which the connecting rod and guide journals work (see fig. 16). More frequently it enters a socket which is a fixed part of the crosshead and is keyed to it (see figs. 8—15). The strength of this connection depends largely upon the amount of draw allowed for keying up, that is to say, the amount of compression that takes place between the rod and socket when the key is driven in; the ageing of the rod, it sometimes requiring a pull of 4,000 lbs. per sq. in. to start an old rod from its socket; the strength of the key;

he strength of the socket. Sufficient to say that seldom
rt give bother, and then only when some employee,
k of knowledge or direct negligence strains or breaks a
stance, a common sight in any railroad shop is to see a
iving in a key with a five ton blow, when a little
filing of the tight part would have done the work far

al method of connection is shown in fig. 22. Here the
the key on the socket and the opposite pressure of the
he socket hold them fixed.
may be caused by lack of metal, but they are more fre-
result of misfitting or misdriving. See fig. 23. The
broken or the socket may break out in triangular pieces
when the rod does not fit tightly into the socket, and
uence gives rise to a "bump." Or else, if the key is
o hard, the rod end may break at "a, a."

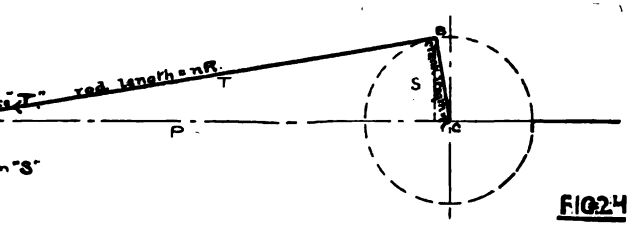


FIG 24

e now followed the development of the crosshead from
form, to its most modern design. We have
main features of its construction, and looked
comparative strength of its details; perhaps it
e out of place to here make a small forecast. The in-
rn engineering development points us to that stage
ocation shall have become a dead issue, and where ro-
ppear in each and every form of motion. The advent
turbine to marine and stationary engines only pre-
vent to locomotion. In such an era, the crosshead will
into history, and the many integrals of work now
it in friction shall be reckoned with as useful motive

The following papers were read at the Annual Meeting, January 24th to 26th, 1905:—

PAPER No. 219,

CONSTRUCTION OF CANADIAN NIAGARA POWER COMPANY'S 100,000 H.P. HYDRO-ELECTRIC PLANT AT NIAGARA FALLS, ONT.

By CECIL B. SMITH, Ma.E., M. Can. Soc. C. E.

When the writer became Resident Engineer for this Company in August, 1901, he found that the location of the works and discharging tunnel had been already decided upon, and a shaft for tunnel construction partly sunken, and, under directions from Consulting Hydraulic Engineer Herschel, the turbine units were being given preliminary study by Escher, Wyss and Co., who also finally designed them.

Aside from the tunnel, which evidently should be built at once of full capacity, the construction then authorized was for a canal of 50,000 h.p., with temporary cribbing on the south side, a wheel pit for 50,000 h.p., and machinery and power house for 30,000 h.p.; but the company in 1902 decided to build the canal for 100,000 h.p., the wheelpit for 110,000 h.p. (one 10,000 h.p. unit as a spare), to erect a power house for 50,000 h.p., and equip it with machinery to the same extent; and this plant, along with conduits for carrying underground cables to Niagara Falls, N.Y., and to a transformer station for 25,000 h.p. outside Queen Victoria Niagara Falls Park, is now practically completed, and is in partial operation.

COFFERDAM.

Some hazardous and approximate soundings had been taken in the Niagara River at the canal entrance, but they gave assurance that the depth of water adjacent to shore was sufficient without extending operations very far out into the rapids, and a cofferdam was built on the location shown on Plate 1., which also gives details of the cofferdam itself.

It will be noticed that these cribs, if placed separately, would have been in rather unstable equilibrium, and the contractor accordingly sunk them in pairs, with turnbuckles in place, using temporary binding timbers to hold each two cribs in correct relative

PRELIMINARY OPERATIONS. SITE OF PRESENT POWER HOUSE.

ion until sunken into place, after which these timbers were re-
d by divers.

The soundings for each crib were taken from a platform extend-
ut over the water from the cribs previously placed, and the
ms of the cribs were framed upside down, so as to fit the in-
lities of bottom, denoted by the soundings. A floor for sustain-
he rock filling was also placed in each crib as nearly as pos-
to the bottom, and the cribs were partly loaded before being
ed into place.

In order to hold on to the cribs when placing them in a cur-
of 10 to 12 feet per sec., several lines of wire rope operated by
ting engines were used, and only one mishap occurred, when
bottom of the large corner crib was torn off. It was found ad-
ble to add vertical binding timbers, not shown on plan, when
s were to be placed in the heavy current. These are being
d of advantage also during the removal of the cofferdam.

The puddle used was composed of about 2-3 gravel and 1-3 clay
ically mixed, as a natural mixture could not be obtained within
asonable distance, and this mixture was found to fall quickly
place whenever leaks opened up, and could be rammed into a
ectly water-tight mass. It was found best, however, to keep the
dle wall well below water level on one side, so as to enable leaks
e promptly reached and the puddle to settle quickly.

The continuous decking was built in place as soon as cribs were
d with rock, and being tied across by timbers above water and
buckles below, the cofferdam acted as one mass.

In placing tongued and grooved sheeting, it was broomed down
and mauls on to natural bottom, and fitted snugly around tim-
ties and turnbuckles, after which all openings at bottom, located
divers, were made tight by piling bags of rich cement mortar,
ramming them into the apertures.

When the cofferdam was pumped out by a battery of 12" 10"
8" centrifugal pumps lifting about 10,000 gallons per minute, it
found that there was, even after temporary leakage through
dle had been cut down to nominal proportions, a heavy flow of
er through the boulders and gravel lying between the cofferdam
solid rock, and as this would have had to be handled for over
years it was considered advisable to take steps to stop it, and a
dle trench was sunk to rock at each end of area unwatered, be-
carried in each case from shore to adjacent points on inside of
erdam. The cofferdam proper was sheeted on inside between
e two puddle cut-off walls, with double tongued and grooved
ting extending from above water level down to solid rock, layers
r paper being placed between the two layers of sheeting, and
der to seal the bottom a toe of rich concrete was carried along

the bottom, being tied to the rock by thoroughly washing the surface of same, and spiking a heavy line of timber, about 12" above the bottom, to the sheeting.

This interior sheeting held the pressure of water against it until torn off when letting water into the canal, and the whole leakage was cut down to about ½ of the capacity of one 8" pump, during this period of over two years.

Bridge.

The original intention of the company was to build a steel bridge across the entrance canal, to carry the tracks of the International Railway Co., and to provide width for a park drive and a sidewalk, and the plans approved by the Park commissioners showed this class of bridge.

When, however, it was decided to build the whole canal at once, the company and its engineers decided that the style of construction to be used for canal walls, power house, etc., demanded a bridge in keeping, and accordingly a stone and concrete bridge 55 feet wide, composed of five spans of 50 feet each, and costing nearly 100% more than a steel bridge and piers, was designed and built. Plates II. and III. give details of construction. The most interesting feature of design was to obtain a bridge with high springings and low crowns, as the difference in level between the water of Niagara River and base of rail was very limited. This was obtained by using steel arch trusses and concrete filling; and various studies of stone parapet walls, seeking to give satisfactory proportions and chasteness of outline have, it is believed, been successful. There are five 50 ft. spans, and when building the bridge an allowance of ¼" was made for settlement, but this much has not taken place, although a curious condition has arisen of the arch rings settling slightly away from the parapet walls, which carry their own weight without appreciable settlement although two expansion joints were placed in parapet walls above piers.

Canal and Forebay.

Plates IV. and V. show the general lay out of the works and typical section of canal walls, which were carried out to the river entrance by 50 ft. curves, and from the bridge, westward, expand out into a forebay 570 feet long.

It will be noticed that these walls are second class rock-faced coursed ashlar backed with 1:3:5 concrete, and plans were also prepared showing solid concrete walls below low water, but the use of concrete as a facing to be presented to the wear of moving water ice laden, although at a slow velocity, was not approved of by Con-

BRIDGE AND OUTER ICE RACK.

neer Herschel, and the present plans were adopted in-
siderably increased cost. The same remarks apply to
and to inlet breast walls.
ducting all losses the net effective head that this plant
o operate under is 136 feet with all wheels running
is head about 8870 cubic feet per sec. will be the maxi-

ount of water will pass through the bridge openings at
et per second with river at normal level, but in the
er the same condition, the water will approach the line
l arches, supporting the forebay room, at only 1 ft. per

gara river is, of course, never frozen over at the canal
t after a prevailing east wind the drift ice from Lake
frazil ice formed in the rapid immediately above the
down in a steady flow from 50 to 100 feet wide,
Canadian shore, and prepared to float into the canal
flow of water creates a tendency or draft in that direc-

t was proposed to allow this ice to float freely into the
rebay, depending on the submerged arches to hold it
e fine ice rack in front of inlets, and on the ice sluice-
on Plate IV. to carry it back to the river, but the writer
protection along the river face to be of inestimable
n outer ice rack was added. This rack is supported
first-class masonry piers 29 feet centres, and consists
otwalk with never-slip plates and another steel beam
ower; these carry 2" rods spaced 12" centres, extending
w and 4 feet above meanwater level, and sloping at 30°
s down stream. This rack will keep all heavy ice out,
t current will roll it along the sloping rods, and should
desirable a steel curtain can be suspended outside the
wn to 3 or 4 feet below water level, thus shutting out
ice, but it is not expected that frazil ice can be kept
orebay, as it comes down the river mixed in the water
bottom.
orth end of the forebay there is a weir with three
enings, two outside and one inside the forebay
fall of nearly two feet can be utilized in the winter
ose of creating a cross current in the forebay, thus
raw the floating ice back into the river, but the writer
ieve that the effect of this weir will be felt for any
ce away from the north end of the plant, although by
es of floating booms diagonally across the forebay a
t of floating ice can be poled toward the weir and thus

passed back to the river. When not in use the weir will be closed by steel lift gates to above the water level of the canal.

The ice protections thus far mentioned will not keep back frazil ice, but no doubt the slow current in the forebay will allow a large proportion to rise to the surface, while the remainder will pass under the submerged arches into the forebay room, where there is a continuous line of fine ice racks resting at a 30° slope against the main inlet or breast walls.

These racks are carried on a steel framework, and are composed of 3" × ⅜" bars on edge, spaced 1 13-16" centres, built into groups 3' 6" wide, by three tiers high; the bottom tier is 3' 0", the centre 11' 0", and top 9' 0" high, the centre ones being movable and capable of being raised up to the top, and of being held there by hooks designed for the purpose.

The functions of an enclosed forebay room will vary with the direction of current approaching the power house, and whereas this direction is parallel to power house No. 2 of the Niagara Falls Power Company, it is practically at right angles to that of the plant now being described, and therefore all floating and suspended ice adjacent to the submerged arches will, in time, pass under them and enter the forebay room, to be dealt with there by means of a travelling forebay crane, and men using rakes and poles.

However, even in this power house, an enclosed forebay room is of great value, affording comfortable quarters for men fighting ice in stormy weather, and moderating somewhat the temperature of the ice rack.

In extreme cases the centre sections of the ice rack are raised up, and the accumulations of fine floating ice and frazil are allowed to pass through the wheels, whose large ports will take care of considerable quantities of fairly large ice without any injury to the bronze runners.

The water, after passing the fine ice rack, enters 18 ft. openings in the masonry inlet walls, thence passes through cast iron penstock mouth-pieces which are elliptical (18' × 12') at the outer end and 10 feet in diameter at the inner end where they pass through the main wheelpit walls, and flows into the upper elbows of the main penstocks. During ordinary operation the movement of water is controlled by head gates set in lubricated cast iron groves in the inlet walls, and operated by lifting screws, a box girder fastened onto the steel columns of the power house, and a 20 h.p. 125 Volt D.C. motor mounted on this girder, and for the purpose of filling the penstocks, so as to release the pressure on the gates, small hand operated wicket gates have been inserted in the main gate bodies.

Outside of these lift gates two sets of stop log grooves have

MASONRY AT N. W. CORNER OF FOREBAY SHOWING OVERFLOW WEIR.

ELLIPTICAL MOUTHPIECE FOR UNIT NO. 2.

A WINTER SCENE IN WHEELPIT EXTENSION—COMPLET
MIDDLE DISTANCE.

at each inlet, so that in case the lift gates require un-
stop logs can be inserted.

WHEELPIT.

it, which is 570 feet long and 18 feet wide, after lining, was
through 15 feet of boulders and gravel, 100 feet of lime-
d 50 feet of shale, the sides being separated, before blast-
hannelling. The channelling machines are self-propelling
a travel of about 12 feet, the cuts being carried down in
nches, having 6″ batter. After blasting and excavating a
e channelling was again proceeded with, an off-set of 6
ing required for clearance.

he reception of numerous castings, draft tubes, etc., a
ount of excavation was required in the form of recesses,
der to do this without unduly shattering the side walls,
periphery of each recess was separated, preliminary to
by gadding and broaching, the process being that
ll body, mounted on a vertical column and truck,
ing horizontally; by using small charges of dynamite,
ached masses of rock were then blown out, leaving the
walls usually intact.

the wheelpit for first installation of 50,000 h.p. was about
s excavated, the tunnel excavation had been completed to
pit, and in order to expedite the completion of the plant the
ged that the general design should be changed, substitut-
ranch tunnels, turbines resting on the solid bottom, lower
elbows ditto, and draft tubes leading from the wheel cases
anch tunnels, which would admit of tunnel excavation
hed forward, and wheelpit excavation being completed
ths sooner than would be the case if the lower part of the
was to constitute the beginning of the tail race.

nerits of this method had already been suggested by
Vyss and Co., the simplifying of the lower penstock elbow
er solidity of the turbine unit when in operation being
nd, in passing, it is interesting to note that the Toronto
ara Power Co. has adopted this identical design for the
y are now building. However, the view of the consulting
engineer was against the change and in order to hasten
letion of the wheelpit excavation which, on the lower
very much cut up by various checks and recesses, it was
o carry forward the tunnel excavation immediately under-
d bring down the wheelpit excavation on the tunnel roof.
process was fairly successful until about two-thirds com-
nen the blasting from above and below had so weakened and

opened up the remaining shale that wheelpit water commenced to leak into the tunnel, throwing excessive loads on the tunnel roof, and necessitating increased timbering at this place, until finally tunnelling operations had to be abandoned, and the remainder of the pit excavated in open cutting as originally intended.

The after effects of this effort to hasten operations were that the sides of the wheelpit, where excavated by tunnelling, were badly shattered, and before the brick lining could be placed large masses of shale broke away, so that as the brick lining was being put in it was necessary not only to fill up these enormous cavities with concrete, but the walls had to be continually watched and scaled down for fear of accidents.

As soon as excavation was well forward it was decided to take measurements for anticipated movement of the rock walls, and the following table will serve to illustrate what actually took place, it being understood that excavation was being carried forward continuously from March, 1902, to June, 1903, and that the measurements given are only a few of those taken.

TABLE OF WHEELPIT SQUEEZE

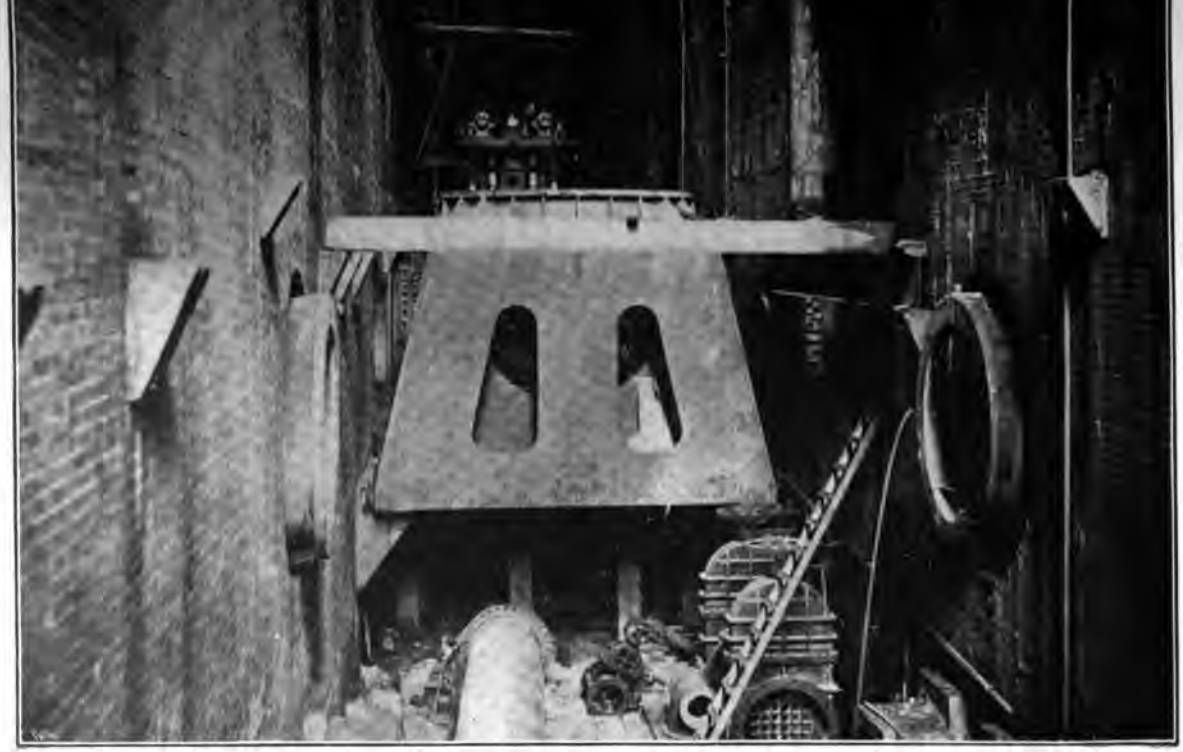
Measurements taken between steel plugs at centre of a pit 275 feet long, and at a point 15 feet below rock surface.

Date.	Total width.	Depth of pit at time of measurement.
July 8, 1902.	20′ 11 1-2″	35 ft.
Aug. 23, 1902.	20′ 11 1-16″	50 ft.
Sept. 10, 1902.	20′ 10 15-16″	55 ft.
Oct. 13, 1902.	20′ 10 13-16″	65 ft.
Nov. 13, 1902.	20′ 10 13-16″	75 ft.
Dec. 18, 1902.	20′ 10 13-16″	85 ft.
March 6, 1903.	20′ 10 13-16″	100 ft.
April 7, 1903.	20′ 10 12-16″	110 ft.
May 8, 1903.	20′ 10 25-32″	125 ft.
Oct. 15, 1903.	20′ 10 7-16″	full depth.

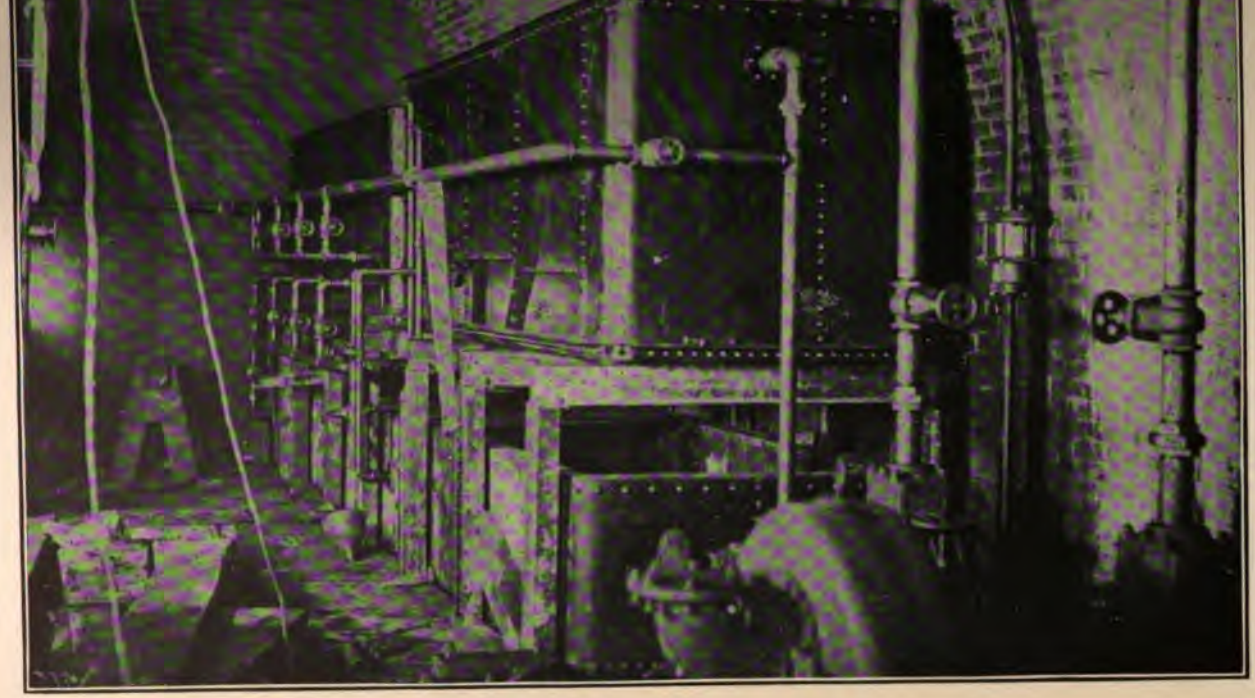
Giving a total of 1 1-16 inches, although at lower levels a movement of 1 1-2 inches was observed between November, 1902, and October, 1903.

Not the least curious feature of these movements was the fact that the east side next the river moved about twice as much as the west side adjacent to higher ground. But the most noticeable fact of the table is that the movements, which had practically ceased by March 1903, had again become serious by October, 1903, and this had been caused by the excavation of the wheelpit extension 300 feet

CAST STEEL LOWER ELBOW OF PENSTOCK.



CAST STEEL LOWER ELBOW OF PENSTOCK.



A GROUP OF OIL TANKS.

eeing one end of the rock walls. This is further shown by ents on thrust girder castings of west wall, which had n September and October, 1902. It will be seen that nents had practically ceased in March, 1903, but again d as soon as the excavations of the extension to pit was wn for some depth.

rst generator arch built was at unit No. 4, and during the f 1904 it became evident that it was being severely and even after several heavy arches had been built, the ining walls of wheelpit at the level of the springing of showed slight movements. It was therefore decided to ew heavy cast iron struts across the pit at units No. 4 , thrusting against cast iron strut bases, which had been n over 20 places in anticipation of trouble.

struts at unit No. 5 and two struts at unit No. 4, each of tons safe capacity, seem to have completely stopped the movement.

TABLE OF WHEELPIT SQUEEZE

al movements of west wall at thrust girder level.

	Unit 1.	Unit 2.	Unit 3.	Unit 4.	Unit 5.
902.	— 1-16″	1-4″	7-16″	7-16″	15-32″
903.	— 1-16″	7-32″	11-32″	7-16″	15-32″
903.	— 1-16″	3-16″	7-16″	11-32″	9-16″
04.	+ 1-8″	1-32″	5-8″	1 1-8″	1″

TABLE OF WHEELPIT SQUEEZE

o. 3 after struts had been placed at various levels at Units No. 4 and No. 5.

Date.	Thrust Deck.	Turbine Deck.
Nov. 14, 1904.	18,882 ft.	16,451 ft.
Nov. 23, 1904.	18,881 ,,	16,447 ,,
Nov. 28, 1904.	18,884 ,,	
Dec. 6, 1904.	18,882 ,,	16,450 ,,
Dec. 13, 1904.	18,884 ,,	16,446 ,,
Dec. 21, 1904.	18,884 ,,	16,445 ,,
Jan. 2, 1905.	18,883 ,,	16,442 ,,

ning of the wheelpit, which consists of 24 inches of solid from invert up to rack deck, and 12 inches of solid backed by 4 inches of hollow brick thence to top, is

anchored to the rock walls by anchor bolts with wedges
large plate washers embedded in the brick work, and, a
was laid with a shove joint with one to three cement m
practically watertight, the leakage through the seams i
passing into the hollow brick and down openings left in
brick lining to cast iron weeper boxes at the rack deck
water falling from them freely into the wheelpit just abo
level.

During the placing of the brick lining a great numl
ings were placed in position. These consisted of the
auxiliary draft tubes, which were buried in the brick
bracket casting section alone of each draft tube weighi
tons) and castings for supporting the lower penstock el
girders, thrust girders, and the various floors placed in
purposes of operation.

These latter castings varied in weight from ½ ton
and extended back from the face of the wall from 3
depending on the loads to be carried, while the lip c
carrying the loads extended only a few inches beyond t
the walls. These castings were, of course, hollow and
with concrete before being placed in position.

Accuracy being necessary, great care was taken as
and longitudinal position. In placing all castings, piano
reel carried heavy plumbobs immersed in water, and
were transferred from one level to another by a steel
had been standardized at Washington, D.C. All work
to 1-1000 of a foo', and, with very few exceptions,
obtained were found very satisfactory during the
machinery setting.

On the east side three chambers, averaging about
× 30′ high, were built at right angles to the wheelpit and
the level of the rack deck, which is the first floor abov
in the tailrace part of the wheelpit.

They were excavated as tunnels by top headings a
but being in limestone did not need timbering. The lin
same as that of the wheelpit, and they were divided up i
levels by steel floors carried on brick ledges on the linin

In the extension of the wheelpit two other simila
being built.

These chambers contain the exciter units, the
forcing water to the transformer station, an air
(Pelton driven) and a system of oil tanks, filters and
supplying oil to the high and low pressure bear
machinery in these chambers will be referred to later on

CENTRES FOR GENERATOR ARCH NO. 4.

GENERAL VIEW OF POWER HOUSE, FOREBAY AND CANAL.

TAILRACE TUNNEL.

inal design for this tunnel was of a section 21 ft. high, ning 16½ inches thick, but this was finally modified to section, which is 25 feet high, and has a composite ottom and sides being of concrete, faced with 4 inches nt brick, while in the arch a brick ring with dry pack-red to on account of the difficulty which would have building of a concrete arch (see Plate V.).

e discharge tunnel was built for the Niagara Falls any there was no exact information as to the value of -efficient for a brick lined channel of such large dimen-g water at a high speed, and even when the present ommenced, the United States tunnel had not yet been full capacity, nor properly calibrated, but an examina-inter of 1902 showed the brick lining, although of a quality, to be absolutely intact, unworn, and slimed ven years' use, with water flowing at about 27 feet per , to make assurance doubly sure, the brick facing of unnel was made of a superior burnt smooth brick, and ade about 20% larger than the earlier one, so that the be slightly increased as the grade of seven feet per nuous, and the alignment of the tunnel very favorable, two curves of long radius with direct outlet in line t (see Plate IV.).

nel is 2,200 feet long, including the headworks at consists of a square headwall 60 feet wide, 12 feet feet high, extending to a depth of 35 feet below water on a foundation well into the Medina sandstone; from the tunnel rises in an ogee curve for some 80 feet to oper, and this portion is lined with 2 feet of granite, considered advisable to use in place of brick, owing ive speed of the water when dropping to the river g understood that the invert of the tunnel at the top urve is at the low water river level.

vation was carried both ways from a shaft sunk mid-the portal and wheelpit and was also carried in red feet from the portal, and although the alignment n two piano wires 12 feet apart, suspended in the shaft, nt work at point of meeting of headings was found to rfect, which must be looked on as a result of extreme se of plumbobs, and taking the average of a large bservations in this and surface instrument work.

the upper portion of the tunnel being in shale, it was carry a full timber roof consisting of 5 centred 12"

× 12" rings four feet apart and three inch lagging, a
put in place, along with the wall plates, as fast as
were driven, while the plumb posts, carried down
were inserted at the time the two benches were bein

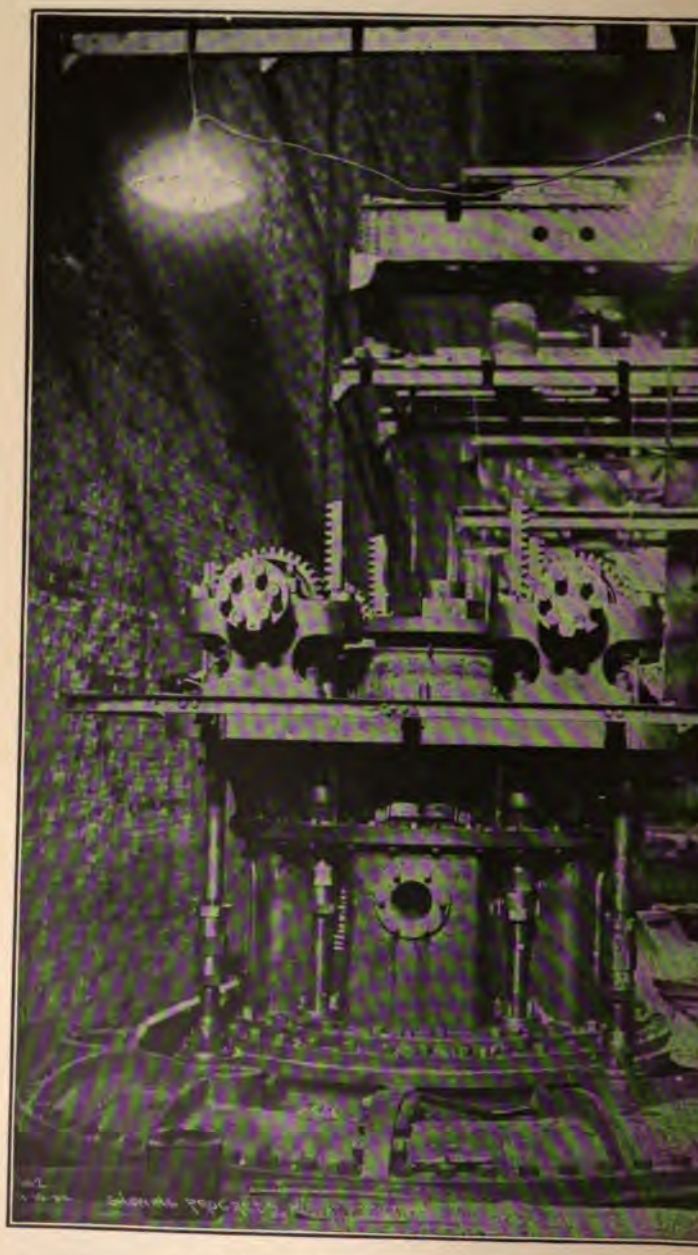
The original idea was to use yellow pine timber
modified by substituting hemlock for centres and
where the stresses would be compressive, and, altho
much abused by blasting, the result was satisfactory,
absence of much water to soften and swell up the s
portion of roof adjacent to the wheelpit was subjec
when the pit excavation was being done just abov
level, and at this point the roof timbers were badly
the centres settled several inches, the fibres of
segments being forced into one another.

The process of lining the tunnel was as follows:-
invert (1:3:5:) being laid, the vitrified brick invert v
far as the corner specials, side forms were then put u
wedged back 4½ inches, was placed as high as the fi
brick headers. After the concrete side walls were bu
height, the lagging was removed, and the brick facing
and including a header course, after which the pro
peated to the springing, the only variation being tha
was used between and behind the plumb posts, in pla
shown on plans.

The brick arch was built in the ordinary way o
and 4" × 4" lagging, a night man building in the key
work done during the day, and laborers placing dry
the haunches and driving it home against the roof
removing centres after being in position two or thr
bringing them forward to a new position.

After side forms and arch centres were removed
tunnel was scraped clear of all mortar with sharp ir
ing the surface smooth and clean. It is believed th
friction co-efficient will exist in this tunnel, especial
walls become slimed over with deposits from water
formed on the walls of the Niagara Falls Power Com
The shaft for this tunnel was sunk from May
1901. Excavation was completed December, 1902
and headwall in May, 1904, after which the shaft wa
and outlet excavation at portal completed during th
1904.

No attempt was made to hasten the completion o
of the plant before the machinery installation deman
wise much greater speed could have been made.



10,000 H.P. TURBINE UNIT AT BALANCING PISTON

POWER HOUSE.

superstructure covering the generators and switchboard, heavy steel framed building, at present covering five 10,000 s, but the design is for a complete building 600 feet long, 11 10,000 h.p. units, with main entrance at the north end. II.).

main building is 40 feet high to the eaves, and has crane 31 feet above the floor, this height being necessary for movement of large loads from one part of the power house er, after the machinery was installed. The proper light obtained by large arch windows below the crane girders, ries of smaller square ones just below the eaves. The ex- alls are of Queenstone gray limestone, with sufficient tool- rich, quiet appearance; and the interior lining consists of otting of enamelled brick up to the window sills, then a se of green veined Vermont marble in line with the marble sills. Above this the lining will be buff brick, which will pleasant well-diffused light. There is an arc light on each he power house every 24 feet.

roof of the main power house is of steel and terra cotta the tiles being interlocking green Ludowici, pointed with and the eaves are carried well out with a slight upward ding in heavy copper gutters.

forebay room is attached to the east side of the power shown on Plate VII., and has a flat steel and concrete le roof, with an asphalt and tile floor. It is surmounted ne parapet wall with 24 foot panels, it being proposed to ctric light columns and flower vases at the panel posts; r the purpose of throwing light into the room itself, in to arch windows every 24 feet, there is a wide continuous in the roof adjacent to the power house; in the forebay -ton travelling crane spans the whole width, and will assist g racks clean, and lifting them when necessary.

he main window frames are metal, which leaves only the sash, and small upper window frames of wood, so that y speaking, the building is strictly fireproof. At the north main entrance door will be of bronze with carved mns, and surmounted by a panel containing the company's ile stretching across the north end of the power house will tors' gallery, from which the best view of the interior of ing can be obtained.

UNDERGROUND CONDUITS.

rder to convey current from the power house two lines of were constructed ,of the style shown on Plate VI., one

of which, 2,200 feet long, leads to a transformer statio
side the public park, and the other, one and a quarte
extends from the power house through the park to th
arch bridge. The four-way ducts are embedded in a
gravel concrete, and are spaced generously so as to p
heat radiation, it being found that in a large group
centre ones do not have the carrying capacity of the

The manholes are also entirely of gravel concre
drained thoroughly with six-inch tile, into which ar
farm tile, laid alongside the ducts themselves; and a
divides the manholes into two parts, while a further
case of fire is obtained by soapstone slab partition
zontally between each group of cables. The ordinary
hole carries the cables straight through without an
bends, the plan shown on Plate VI. being a special,
water main shown is for carrying water from the p
in the power house, to the water cooled transformer
pipe situated outside the park on the company's land

Transformer Station, Etc.

On the tableland, immediately west of its works,
has acquired a large tract of land, and on it has
transformer station of 25,000 h.p. capacity, 80 feet wi
long, having a main central room 38 feet wide equi
15 ton Whiting electric travelling crane, copper oil
pump and motor, and cast iron jack rails, resting
foundations. On these rails there has been insta
present, 12 transformers of 15,000 K.W. total c
equipped with water cooling, drainage, and lead lined
systems. These transformers are for 40,000 or 60,000
sion, and are separated from the low tension and
switchboards by solid brick curtain walls, the cables
to the transformers through passages underneath
floors and carried from them through overhead ar
curtain wall, thence to the high tension switches, fr
wires will pass out of the building through speci
windows.

The building itself is of pressed brick, with sto
Ludowici tile roof, and is entirely fireproof, except w
It has a central monitor roof for light and offices ne
entrance, which is a door of capacity for fully loaded
to enter far enough to transfer loads to the crane.

Adjacent to this station has been built a stand p
diameter by 116 feet high, which is connected to the

STANDPIPE FOUNDATION.

wheelpit to transformer station, and the flow of which is controlled by a motor driven valve operated nsformer station, the object of which is that in case and pipe can be cut out, and the two pumps at the working tandem, can raise the pressure of water to nsformer station floor line during the fire period.

tion of this standpipe, however, is purely one of re- of a breakage of the pumping and pipe systems e transformers with water for cooling, in which event e capacity is estimated as being sufficient for 50,000 ours, or for 48 hours for the present station.

of the importance of continuity of operation this safe- gh costly, was considered necessary; indeed, speaking nent in general, every effort was made to design the o obtain a maximum of reserve in cases of break-

Power House Machinery.

lling materials two fifty-ton four motor electric travel- were installed, which, by working with a carrier, can dle practically 100 tons. These cranes operate with . current, and have auxiliary five-ton hooks for fast light loads. The Sellers cranes, which are the ones ave as a distinctive feature, fixed drums, the carriage ng. The speed requirements with full loads were:— 0 ft. per min.; auxiliary hook, 50 ft. per min.; trolley 50 ft. per min.; and bridge travel 200 ft. per min.

n turbines have twin draft tubes emerging into the pit immediately above the invert, and, owing to the of water which there will be normally in the pit with ant in operation, not to speak of the effect of back high water in the lower river, it was necessary to rbines about 47 feet above the invert of the tunnel, and pressure is equivalent to about 33 feet water head, it found practicable to operate safely with more than aft tube effect, which necessitated some artificial means pondage in the wheelpit with only a few wheels in

ult was obtained by installing a huge regulating lift extreme lower end of wheelpit, where connection is he tunnel, and operating the same by lift screws, over- and 85 h.p. 125 Volt D.C. motor (a second motor in he water will pass under the gate, and in order to re- tant vibration, very heavy cast iron grooves, grouted nto the brick lining walls of the wheelpit, rest against

masonry specially cut and built into these walls to
grooves, and the gate is equipped with an oiling sys
a flexible piping.

The 10,000 h.p. turbines are described as twin
charge, Francis type, operating at 250 rev. per mi
feet net effective head, and have solid bronze runners
and cylinder gates, controlled each by four racks and
racks move on opposite sides of the pinions, so that
as the mate to it lowers, the whole movement for ea
controlled by a connecting rod from the Escher W
situated on the power house floor.

The revolving parts of a turbine and generator,
connecting them, are supported as follows:—In addit
ward thrust on the lower runner, there is a bal
located immediately above the wheel case, and the p
unit is directly supplied with water from the foreba
inch pipe, but as a reserve, in case of accident, there
nection with each penstock.

In addition to this there is attached to each mai
diately beneath the generator a thrust bearing.
operated with high pressure oil, of carrying the whole
revolving parts of a unit, which amounts to about 243
bearing is fed from the oil chamber with oil, which
high pressure by a pump located immediately alon
thrust deck; after leaving the bearing the oil flows
chamber to be cooled, clarified, and pumped bac
thrust deck. The turbine shafts are hollow seamles
inches in diameter with weldless flanges, which con
lings to nickel steel bearing shafts 14 inches diam., b
the various bearings and connections, there being,
Plate IX., two intermediate bearings for supporting
tween the thrust bearing and balancing piston.

The main penstocks each consist of a lower cast
two sections, weighing 49 tons, which sits astride of
carries the weight of the penstock and the water cont
above this are five straight sections of rivetted pipe
and a half inches in diameter, having weldless steel f
expansion joint connecting to the cast iron mouthpiec
wall by a steel upper elbow. The calculated speed
with full load on a unit is about 11 feet per sec.

Five units of 7,500 K.W. output each, make the pr
tion, but the plant is built for eleven such machines,
being counted a spare, and in order to increase the p
it will only be necessary to extend the power house
install such machinery as may be required.

TUNNEL PORTAL HEADWALL.

pplying the various water-driven machines in the cham-
dependent water system has been installed, which con-
6-inch rivetted main with weldless flanges, along the
fed from the canal by two 36-inch and five 24-inch ver-
Of these, one 36-inch and two 24-inch pipes are in the
ation. From this main, which is sub-divided by valves
points, rising pipes enter the chambers and, after
he machines, the water passes by draft tubes into the
ow.

chamber is located an exciter plant, making 125 Volt
t, which is used not only for excitation of large genera-
r operating cranes, switches, various gate and pump
l lights, etc. This plant consists of three vertical direct
nits of 332 h.p. each, the turbines being single, spiral
d and downward discharge, running at 600 rev. per min.
t. head, and controlled by Lombard governors. These
oil bearings supplied with low pressure oil from the oil
nd are each quite independent, so that any unit can run
her two shut down for repairs.

cond chamber are located two pump units. Each unit
a horizontal turbine direct connected to a centrifugal
000,000 galls. per 24 hours capacity. These pumps can,
emarked, be run in tandem in case of fire so as to pro-
pressure at the transformer station of 120 lbs., with a
the pump of 210 lbs. per sq. inch. The turbines are
the 36" auxiliary main and discharge into the tailrace
bes built into the brick wheelpit lining, while the pumps
water from one of the 24" supply pipes from the canal
ge by a 24" pipe up the wheelpit, and thence out and to
rmer station, a half mile distant, by a 12" water main.

ird chamber there is a very complicated system of motor
driven Quimby screw oil pumps, oil tanks, filter tanks,
tanks, all so inter-connected as to produce necessary
which consists, briefly, in there being two circuits, one
essure and one for high pressure oil. The oil traverses
hine back to the cooling and filter tanks, thence to the
ks, from which it is again pumped back to the machine.
ressure oil is handled in the same manner, except that
ump is located at each thrust bearing, and raises the oil
these bearings, after which this oil also flows back to
mber to be cooled and clarified. In this chamber is also
designed Pelton driven air compressor, and in a cham-
upper level adjacent to the main subway are located
ks of large capacity for storing oil, while a pressure oil
located in the roof of the power house.

The main power house floor will contain only t equipment, namely, the 7,500 K.W. generators, the ernors, and the main switchboard. So that the vi visitors' gallery will be one of extreme simplicity, as of the generators are external and stationary, and are very innocent looking machines in line with the not observable from the north end of the power hous ators are about eighteen feet in diameter, with inte fields, and deliver three phase 25 cycle current at 12,0 was adopted in order to enable local distribution fo to be made without transforming.

As these generators were both too large and t transportation it was necessary to have them comple at the shops, then taken apart and packed in hundred shipped knocked down to the works, where it took to re-build the fields and armatures piece by piece, t is understood, 47,000 punchings in each armature.

Plate VII. shows two subways just below the pow one to the right being for cables, and the main one cables and for the substructure of the main switchbo each 50,000 h.p., is about 150 feet long. The subway full 600 feet length of the plant, and has a series of ing off to the left, one at each inlet breast wall, whi voted to miscellaneous purposes, such as location f formers, etc. The main switchboard consists of a lo subway, made up of bus-bar compartments, divided u brick walls and horizontally by soapstone slabs, a motor operated oil switches, and above the power switchboard proper from the gallery of which a full power house is had, and which is equipped with swi for full control of the station.

Cables leave the power house by three manhole at each end and one at the west side, from wher through conduits, already described, either to the tr tion or to Niagara Falls N.Y., to deliver current sup that generated by the Niagara Falls Power Company. are lead covered, 2½" diameter, and contain three p copper conductors, each ½ inch diameter, which ar paper and gum wrappings, the whole three being a by similar wrappings beneath the lead covering.

The ground for this plant was broken in Septem though the tunnel and cofferdam had been nominal somewhat earlier, and water was turned into the fo 1904, the exciter chamber was ready for operation N and the 1st 10,000 H.P. unit December 23rd, 1904.—

CONDUIT CONSTRUCTION.

TUNNEL PORTAL EXCAVATION.

s were ready for operation January 1st, 1905. The third put in operation in a few months, and the fourth and uring the summer of 1905, while the extension of wheel-e, brick lined, and ready for the machinery of the re- units should be completed during 1905.

be appreciated that during this period Queen Victoria two other large and one smaller plant under construc- a state of great chaos, and this is largely the case at time, but the companies are under obligations to place tive areas in good condition as soon as construction is d when this has been done the southern part of the was always in a state of nature, will be vastly im- e Canadian Niagara Power Company, in process of con- lled in the foreshore of the river for about 100 ft. in the Horseshoe Falls southward for over ½ mile, and also sodded and added to the park area.

ncipal contractors connected with the works were:— y, cofferdam; Dawson & Riley, wheelpit and canal; Quarry Co., arch bridge; A. C. Douglas, tunnel and por- race Co., power house; Brass Bros., transformer sta- r, Wyss & Co., turbine units No. 1 2, 3; I. P. Morris units No. 4, 5; General Electric Co., generators and n-board; Jenckes Machine Co., exciter turbines; West- Electric and Manufacturing Co., exciter generators; eneral Electric Co., transformers; Canada Foundry Co., gates, etc.; Hamilton Bridge Co., power house steel ldition to which a great many contracts were placed nd United States for various pipings, steel floors, smal- ry, etc. The policy was at once established of having and thorough inspection in keeping with the rigid spe- nd high class of work demanded, and a large number rs were employed, who were located at the various ng centres and on the works itself. As these men e best that could be found for the various classes of done, it is believed that the results warrant the large xpenditure. For mill material, the Pittsburg testing did the inspection.

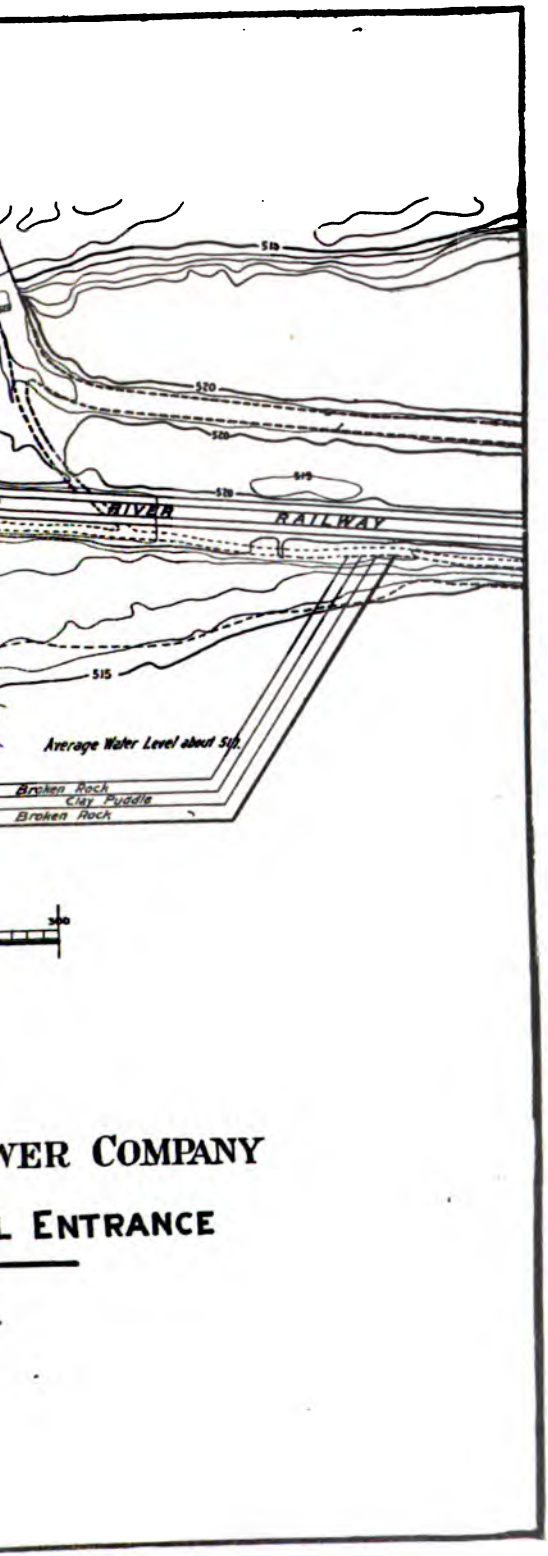
complete study, design, and execution of such an under- as just been described, the engineering department was somewhat complex, there never having been any chief ther nominal or actual, the organization being as fol- f mechanical engineer, Dr. Colman Sellers; consulting ngineer until December 31st, 1903, Clemens Herschel; engineer until March 1st, 1904, W. A. Brackenridge; gineer in charge of construction, Cecil B. Smith; Elec- eer, H. W. Buck.

Speaking generally, the designing was done unde
of Consulting Engineer Brackenridge and by the
of the Niagara Falls Power Company in charge of A
until March, 1904, since which time the writer assume
ridge's functions, but the liberal policy of the compa
the main points of design were determined after ful
the various engineers mentioned.

In carrying on the work of construction the co
the writer full choice of whatever staff was consid
and to employ also such inspectors in different br
needed. The chief assistants were as follows:—Pri
engineer, G. A. McCarthy; assistant mechanical
Egbert; assistant electrical engineer, G. E. Brown
gineer of wheelpit and canal, Wm. Macphail; assist
tunnel, L. Sherwood.

To these gentlemen the writer wishes to here
treme appreciation of those qualities which made
carry on such an extensive work with satisfactory
that harmonious spirit which prevailed from the
of the work until the time (Dec, 1904), when the w
his engagement with the company.

GROUP OF DIRECTORS, OFFICERS AND ENGINEERS.


510
520
520
510
SHIVER
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Average Water Level about 510
Broken Rock
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300
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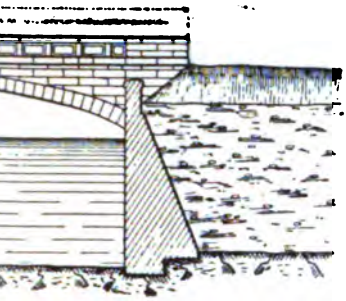
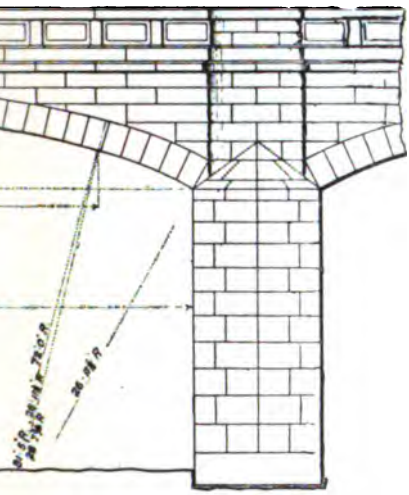
L ENTRANCE



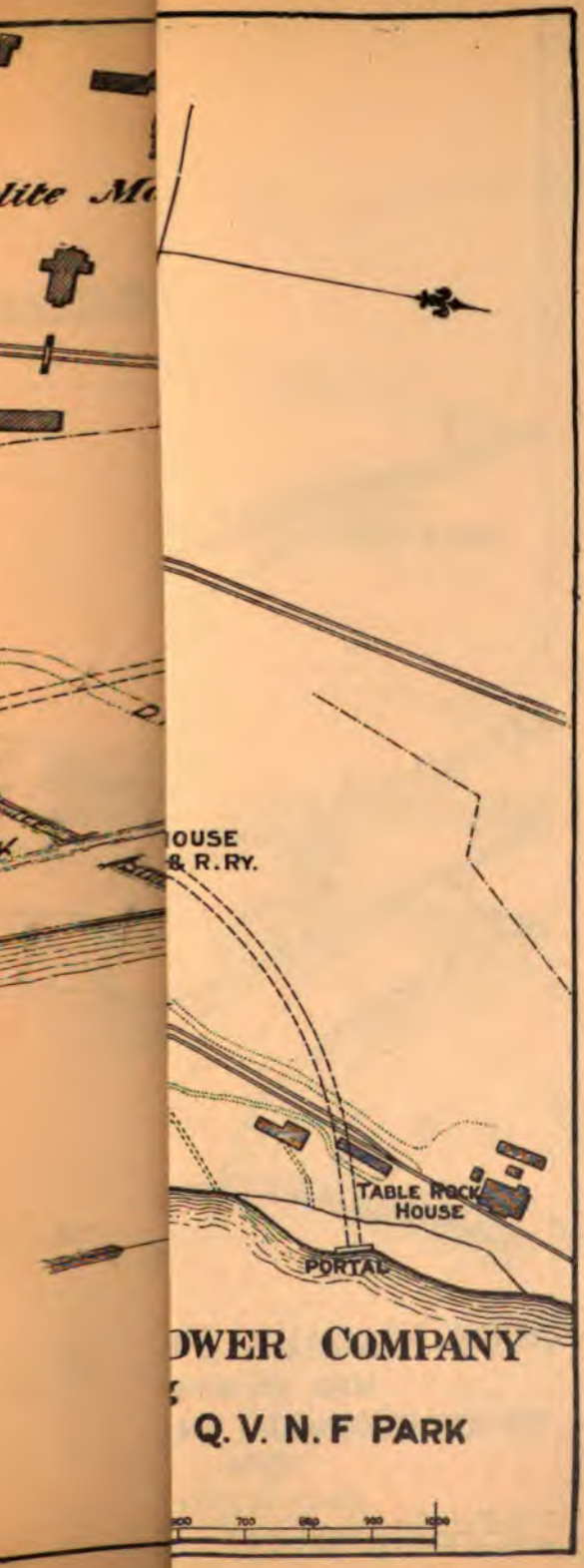


RA POWER COMPANY

OVER CANAL INLET

1902

El 526.86
Catch Basin
NY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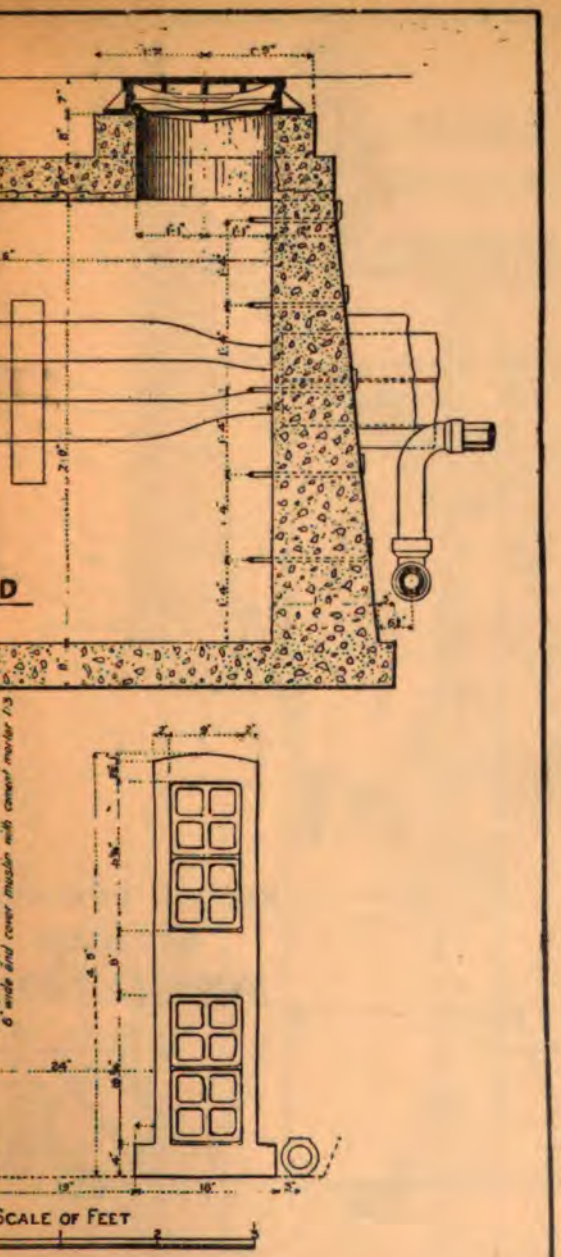
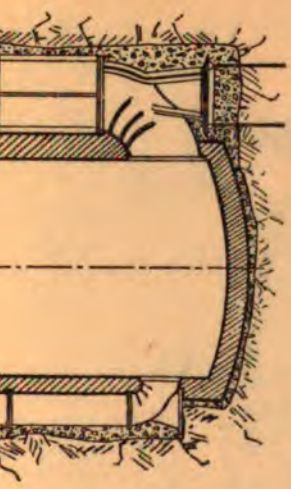


ARA POWER COMPANY

ROM POWER HOUSE TO

FORMER STATION



r. Baillairgé.

IT

CORRESPONDENCE.

. C. P. Baillairgé, in discussing Mr. Smith's paper, wrote that Mr. Baillairgé.
e 64, under the heading of "Canal and Forebay," Mr. Smith
itten as follows:—

will be noticed that these walls are of second-class rock-
coursed ashlar backed with 1:3:5 concrete.

ans were also prepared showing solid concrete walls below
ater, but the use of concrete as a facing to be presented to
ear of moving ice-laden water, although at a low velocity,
ot approved of by Consulting Engineer Herschel, and the
t plans were adopted instead at considerably increased

. Anderson, in his retiring address as President of the Cana-
ociety of Civil Engineers, in referring to concrete construc-
aid:—

ncrete is now largely used in Canada to replace the more
sive cutstone previously used in heavy foundations, and in
abutments. Culverts have been built in concrete on the
a Atlantic and other railways, and illustrations will occur to
member, of works in which concrete has been used with most
ctory results. This applies particularly to a country in
masons or skilled laborers of any kind are scarce and ex-
e and the resultant quality of masonry questionable."

e piers of the Interprovincial bridge over the Ottawa between
nd the Capital are also of concrete, below as well as above

Baillairgé continued that some years ago in a discussion as
relative merits of stone and concrete for certain portions of
rbour Works and Custom House landing piers and steps, he
pressed himself as fully of the opinion of Mr. Herschel, that
egard to angles of piers or their arrises, there was danger
ion by swiftly moving ice-laden waters, though he had not
o far as Mr. Herschel in including breast walls where the
of ice being merely attritional and not aggressive, is not
to strike or exercise a thrust, as it might do against the
of a pier, and could, therefore, have no disintegrating or
tive effect.

reporting quite recently to the ecclesiastical authorities in
, as to the opportunity of using concrete or artificial stone
erection of churches, school-houses, etc., in situations where
s scarce or costly of transportation, he had recommended
terial where passenger traffic and ordinary vehicular traffic
ot likely to wear away the angles or arrises of concrete con-

Mr. Bail'airgé. structions; leaving it to be inferred, of course, vehicular traffic obtained, the quoins of build thrust against by heavy trucks and loads, migh bridge piers, be endangered by erosion, disinteg away of the concrete to an extent rendering it stone quoins at all such salient angles.

Under the circumstances, the opinion of Mr would be most interesting as to this pertine resistance of the salient angles or arrises o others to erosion by moving ice, so as to arrive in regard to land structures under analogous c

Mr. Smith Mr. C. B. Smith, replying to Mr. C. P. B wished to say that the draft design for solid canal and forebay and other situations, was on extending from the foundations up to within tw level, while above that point rock-faced limestone to present a masonry face to the abuse of floa etc., and above water for the sake of appearanc water moving not more than 2¼ feet per secon ice in suspension, would be quite harmless in He was still of the opinion that constructing in a have been good engineering, and indeed, leaving of appearance, that solid concrete walls under would have been as durable as limestone, and

It must be understood that the work was a and had about a year in which to harden.

MAPS AND MAP-MAKING IN CANADA.

By JAMES WHITE, Dominion Geographer.

n this brief paper nothing has been attempted beyond a sketch e progress of the mapping of Canada from the beginning to resent time, with notes respecting what is now in hand, what proposed to undertake in the near future, and a list of some -date maps issued by the Dominion and Provincial Govern- s.

. review of maps of Canada would not be complete without notice of the first map containing the name "America"— h no portion of Canada is included in it—known as the Wald- iller map of 1507. The only original copy that has been pre- d is that recently discovered in the library of Prince Wald- Wolfegg, at Wolfegg, in Wurtemburg. Its preservation was, less, due to the fact that its original owner, the cosmographer, nn Schoner, had it bound in an atlas, whilst the others of the on of 1,000 copies were probably mounted as wall maps and hed, owing to their enormous size. The original map is a sur- ngly excellent example of the wood-cutter's art, and is the est known example of the production of a large wood-cut in so plates—12 sheets. It has been reproduced by photo-litho- ny from the original with all the errors and without retouch- It is the irony of fate that Waldseemuller, though one of the nost geographers of his time, is better known in consequence s error—an error that he corrected in his 1516 chart—than of xtensive and important cartographic work.

One of the first maps that showed any considerable portion of Atlantic coast, was drawn in colour on oxhide, in the year 1500 e pilot Juan de la Cosa. It has been a sort of geographical n centre round which the Cabot controversy has raged, the cates of each theory finding proof of its accuracy therein, even e proving requires the abstraction of a portion and its revo- n through 90 degrees.

Up to the close of the sixteenth century Canada (or New ce) was not usually mapped, except as a portion of America e Western hemisphere. Subsequent to about 1590 its increas- mportance, and the fact that it constituted the possessions of ce in the northern portion of the continent, justified separate s, the best of which were, for many years, published in Paris

and Amsterdam. The most notable makers of maps during the seventeenth century were, on the Contin Jaillot, de l'Isle, Berlin and d'Anville, and, in Great Bri Jefferys, Kitchin and Mitchell. The last named is of spe to Canadians, as it is due to the errors in a copy of his —which was used during the negotiations preceding t Versailles—that the International boundary follows the Rainy rivers to the Lake of the Woods instead of as St. Louis river from what is now Duluth.

In 1795, Aaron Arrowsmith published the first of t maps of Canada that have indissolubly connected his the mapping of this country. All the surveys made, geographical information collected by employees of Bay Co. were placed at Arrowsmith's disposal and inco his maps; thus we have new editions of his 1795 map i 1819, 1820 and 1821. This connection gave him a uni far as Canadian geography was concerned—a very a position till the absorption of the North West Co. by Bay Co. in 1821, gave the latter a monopoly, and the re necessary to repair the losses due to the ruinous compe to the union resulted in an almost complete cessation

During the early part of the nineteenth century, th competition between the Hudson's Bay, "X Y," North other fur-trading companies stimulated explorations in o and western territories to an unusual degree—not the results of which was the crossing of the continent Alexander Mackenzie, which secured to Canada what is n vince of British Columbia and also, consequently, a Pacif To make the surveys and map the explorations, these employed several very able men, notably the famous Da son, later one of the Commissioners appointed to del International boundary between Cornwall and the north of the Lake of the Woods—and the comparatively un almost equally able Peter Fidler. It is noteworthy th maps of these geographers are still unpublished, thoug mation has been incorporated in other and later maps a the present time, the surveys of Thompson and Fidle the best information obtainable with reference to some our North West. Thompson's map is in the Crown La ment, Toronto, and Fidler's is the property of the hopes that the Government will some day authorize th tion and thus perpetuate their great works.

In 1815, Joseph Bouchette, Sr., published a map North America, and in 1831, his son, Joseph Bouchette, J a map of the British North American provinces on a sc 14 miles to 1 inch.

In 1844, a geological survey of Canada, under the direction of r. (afterward Sir) William E. Logan, was commenced. Sir Wilm found the surveys and maps so defective that he and his sistants were forced to devote a great deal of their time and ention to topographical work, and he has aptly summarised the ficulties with which he had to contend as follows:—

"Many of the difficulties encountered in making a geological rvey of Canada have arisen from the want of proper topographical ps, and also from the fact that great parts of the country were olly unexplored, and consequently not represented on any map. older countries the labors of topographers and geographers have eceded those of the geologist, and have given correct representans of the surface, rendering the subsequent geological investigan comparatively easy. But in Canada the want of such maps has mpelled the geologist, in many parts of the country, to study its pography as a preliminary to the representation of its geology. ence a great part of the labours of the Survey during the last enty years has been bestowed upon topographical researches, the tent and importance of which will appear from the summary to given farther on. These additional labours, and the unwelcome sk of map-making imposed upon the officers of the Survey, have en the source of great delays in the geological investigations."

In 1866, he published the large geological map of Canada which, th the "Geology of Canada," 1863, will always remain an endurg monument to Canada's first geologist. Since 1866 the eological Survey has made surveys in all portions of the ominion, and has issued about 250 sheets of various sizes and ales, many of which, of course, overlap each other.

Since its very inception, nearly all the maps published by the eological Survey have included a large amount of topographical formation based on surveys made by its own officers—not that e work was undertaken from choice, but because they were forced make them to supply deficiencies and to correct errors in the isting surveys. The attitude of the Survey has been, consistently, e of protest, as this work has absorbed funds that were required r geological work while, at the same time, the publication of e report of the geologist has frequently been delayed, pending e completion of the surveys and, consequently, of the map. While e Survey has thus issued many valuable maps, still as they were ly a means to an end, that is, as they were prepared only for gions that were of geological interest, and in which geological vestigations had been undertaken—many districts that, from a urely geographical and economic point of view are of great imporance, have, perforce, been neglected. Similarly, no up-to-date eological map of Canada has been issued since 1866, the one pre-

pared in 1882 being based on a topographically def
had been compiled for another purpose.

Recognizing these defects in mapping as carrie
the Hon Mr. Sifton, in 1899, appointed the writer to
Dominion Geographer, with instructions to commen
tion of a new map of Canada, in 8 sheets and on a s
to 1 inch. As soon as it was completed the Standar
map of the southern portion of the Dominion on a s
(7.89 miles to 1 inch) was commenced, and sheets co
of New Brunswick, Quebec, western Ontario and s
Columbia are now under way, attention being devo
areas that have been wholly or partially neglected b
zations. The thickly settled portions of the easter
also being mapped on a larger scale, viz., $\frac{1}{250\,000}$
inch), which permits the inclusion of all the d
required. When complete, it will be possible to su
with sheets that are up-to-date and covering any r
of the country. These maps are engraved on coppe
be corrected from time to time by "beating up" the
back. Each sheet includes a definite number of deg
and longitude—3 degrees in the $\frac{1}{500\,000}$ sheets
$\frac{1}{250,000}$ and any number of sheets can be joined t
a map of any desired area. In addition, it is propos
work along other lines that will show forth the eco
—developed and potential—of our country.

The following is a list of the principal areas
have been, thus far, mapped in detail:—

1-mile scale.—Cape Breton Island, Antigonish, G
Pictou, and portions of Cumberland, Colchester an
ties, Nova Scotia.

2-miles scale.—Lake of the Woods, Rocky Mo
vicinity of the Canadian Pacific Railway, and s
Dawson.

3-miles scale.—Sectional sheets on this scale,
about 4,300 square miles each, of Manitoba and
south of approximate latitude 53° have been pu
Department of the Interior.

4-miles and 3.95 miles.—New Brunswick, gre
Prince Edward Island, Gaspe peninsula, southern
Ottawa to Quebec city, vicinity of Timiskaming, Nip
Haliburton, Perth, Windsor, London and Niagara

arge part of the same province west of Port Arthur, also
d sheets including an area of about 20,000 square miles in
British Columbia, the Atlin district and the valleys of
and Macmillan rivers in Yukon, have been mapped by the
and Geological Survey. The Quebec Government has pub-
aps covering the portion of the province lying between a
wn from Temiskaming to Lake St. John and the St. Law-
lso of the portion south of the St. Lawrence and east of
The Ontario Government has issued a 4-mile map of the
portion of Nipissing district, and a 5-mile map of the
between Georgian Bay and the Ottawa.

les scale.—A reconnaissance map of the Rockies between
adian Pacific and the International boundary, and a num-
sheets including a large portion of southern Yukon have
blished. Sufficient surveys to bring the information up to
ile standard were not, however, available for these sheets,
should be classed as 8-mile maps.

les scale.—The greater portion of northern Manitoba,
Assiniboia and of Alberta, also central and southern British
a and part of eastern Saskatchewan, have been mapped on
le. Elsewhere in northern Canada, many sheets usually
some of the larger rivers and lakes and country in the
te vicinity, have been issued, but, while very useful, they
be considered as containing the amount of information
y to make a complete map for this scale.

-miles scale.—The whole of Manitoba, Assiniboia, Saskatch-
nd Alberta and western Athabaska has been mapped on this
the Department of the Interior.

owing this brief resumé of published maps, it will be in
consider what is now in hand in the office of the writer,
at is proposed for the near future.

The Standard Topographical map on a scale of $\frac{1}{500\,000}$
les to 1 inch), and the detailed sheets on the $\frac{1}{250\,000}$ scale
referred to) are under way, and will be pushed to comple-
fast as possible.

An Economic Atlas of Canada is well advanced toward
ion, and will be issued during the current year. It will
maps showing:—

Territorial divisions of Canada.
Relief map.
Geology.
Minerals.
Forest resources and northern limits of trees.

(f) Telegraphs and cables.

(g) Telephones.

(h) Railways—with the territory tributary t systems indicated by colors.

(i) Transcontinental railways.

(j) Canals, and sailing routes and dis ances betw ports on the St. Lawrence and great lakes.

(k) Bathymetric maps of the Atlantic and Paci showing lighthouses, sailing distances and routes t dian and foreign ports.

(l) Isotherms for months and year.

(m) Isobars for seasons and year.

(n) Rainfall and snowfall.

(o) Electrical divisions and counties.

(p) Density of population.

(q) Disputed International and Interprovincial

(r) Routes of early explorers.

(s) Drainage basins, areas and lengths of strea

(t) Distribution of Indian tribes.

(u) Cities with population of over 25,000.

Or about 45 maps in all.

In addition there are about 50 sheets of statistic area, population, agriculture, finance, railways, man largely based on census and customs statistics. Later to accompany the Atlas, and containing a large am tical information that cannot conveniently be in diagrams, may be prepared.

3rd. It is proposed to prepare gazetteers o provinces. They will include maps showing the geol cipal industries, notes re resources, etc. The letter pr descriptions of the foregoing and also a list, arranged, of the cities, towns, villages, lakes, rive etc., with notes respecting the population, industrie municipalities and respecting the area, altitude, leng topographical features.

4th. A "Resource" map of Canada is now in will be on much the same lines as the "Industrial United States.

The writer, at first, proposed to add a list of thus far published, at the same time indicating in the area included in the various sheets. As this wou sitated the inclusion of some maps published by priv

it is desirable to avoid any distinctions that might appear
s, the list has been omitted. However, any person desiring
tion connected directly or indirectly, with the geography
rces of Canada, is requested to apply to the writer and, if
, the information will be given or, if not within the purview
work, it will be referred to the proper department.

PAPER No. 221.

THE EFFECT OF LOAD FACTOR ON COST

By E. M. Archibald, B.Sc.

The great desideratum for an electrical systen
factor with consequent greatest return on investm
being the ratio of average to maximum load. A
expense included in cost of power to the consumer
ing at maximum economy, and cost of power is at

The lighting of residences and offices produce
late afternoon and evening, with but little load t
the twenty-four hours; consequently the average l
with lighting only is very small and the load facto
mercial motor load in connection with lighting w
average load even though causing a greater peak.
a street railway load still further increases the d
consequence of the heavy demand load during the r
the public is going to and from business, which oc
of the lighting load, the peak load on the plant is g
This heavy peak, with but a small average load
four hours, produces a low load factor, and a po
chinery being shut down the greater part of the ti
must be paid by the consumer to secure a certai
investment than when the load factor is higher.

Evidently, when the load factor is 100%, that
is constant throughout the twenty-four hours, and a
is in continuous operation, the cost of power per K.
mum, and the greatest return on investment is real
having a steady load or with high average load ar
and may be offered much better rates than all oth
the endeavour of this paper to determine the de
power with increasing load factor.

The storage battery is evidently a means in
power producing company of increasing the aver
machinery. By charging the battery during light lo
ing during periods of heavy load, a more constant l
rating apparatus is produced, with consequent bett
at the same time acting as a reserve in case of
power plant. Unfortunately the battery is exper
occurs in its operation which greatly reduces the

by the increased load factor. The great benefits obtained
ıse are reserve capacity and voltage regulation, enabling the
more efficient lamps.

e storage battery, however, has not been considered in what
, even where it might be desirable, but rather a plant is as-
of certain maximum capacity for the peak load, and we are
rmine what effect various load factors have on the cost of
produced.

e various expenses involved in the cost of power to the con-
are as follows: (1) management; (2) distribution; (3) pro-
.

a given system with given peak load the cost of manage-
practically constant, no matter what the load factor.

e cost of distribution is constant with various load factors in
as the fixed charges and maintenance is concerned. The
n distribution, however, vary, these consisting of losses in
ransformers if alternating current is used, meters, losses in
and losses from theft of current; all decrease the output
ordingly increase the cost to the consumer. While it is pos-
determine fairly accurately the losses in lines, transformers
ters with varying load factors, the losses from grounds and
e indeterminate and require constant attention to keep them
certain limits. Yet as a rule these latter will become a
percentage of the total output the higher the load factor.

ere yet remains for consideration the effect of the load factor
actual cost of production of energy.

e higher the load factor, the greater is the amount of power
d, the longer does the apparatus operate most efficiently,
er the ratio of fixed charges to total operating expenses and
iently the lower the cost of power per unit.

determine exactly in what proportion the cost of power is
ed, it will be necessary to assume a plant, determine the fixed
riable charges and thereby the cost per K.W.Hr. at various
ctors.

us take for example a plant with a peak load of 750 K.W.
hree units of 300 K.W. capacity each, so that in case of a
lown to one, the other two may take care of the peak with
load of 25% on each and sufficient boiler capacity for the
ontingency. No provision is allowed for stokers, coal hand-
paratus or economizers. Plant assumed to be on the water
roviding sufficient water for condensing purposes.

rves are also plotted for a second plant of the same capa-
the first, but operating non-condensing. In both cases
water or railroad connections assumed with convenient faci-
or coal handling and removal of ashes.

First cost of plant complete:—

Condensing, $118,425.00 equivalent to $131.60 per K.W
Non-condensing, $114,625.00 equivalent to $127.40 per

Fixed charges.	Condensing.
Interest at 5%..	$5,921.25
Taxes and insurance at 2%..	2,368.50
Depreciation machinery 10%.	7,710.00
Building 3%..	1,122.00
Total..	$17,121.75

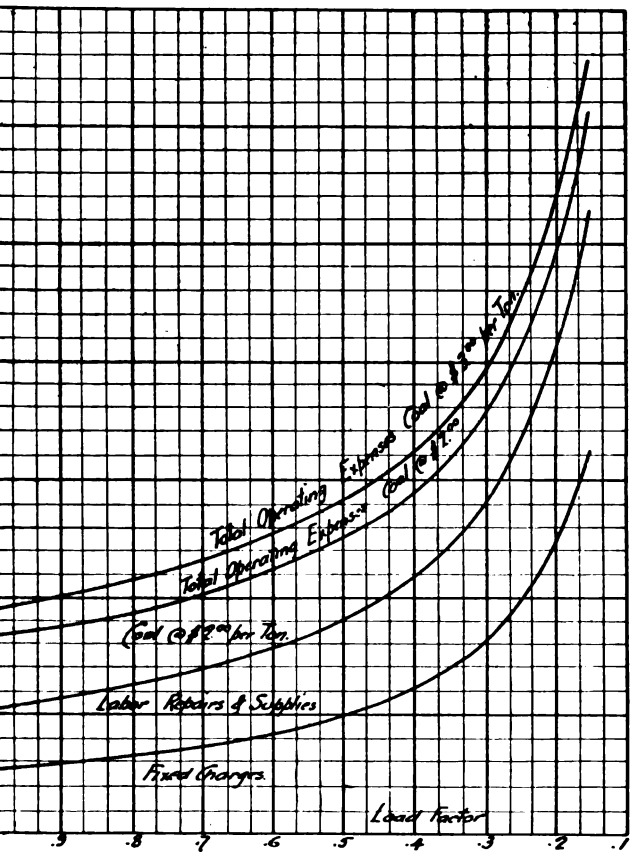
The above first cost being for 100% load factor, t
varying reduction due to the decreased boiler capaci
lower load factors. A point is reached below which i
able to further decrease the boiler capacity as the p
be taken care of and sufficient reserve provided for
repairs; this point being taken in this case at 40% los
effect of this reduction is to diminish the fixed charg
factor by $1,000.00 per year, or about 6% of the total
figures the lower line in figs. 1 and 2 are plotted an
effect of fixed charges on the cost of power.

The remaining items of expense are what are ge
operating charges and are variable with load factor.
of (1) labor, oil and waste, supplies, water and repai

The cost of labor varies to a certain extent wit
but a minimum number of men required to operate
reached at about 40% load factor, below which this
constant. The cost of oil and waste, supplies, wat
varies almost directly with load factor as the greater n
per day that the machinery remains in service, the gr
expenses become, and vice versa. The second line i
is for these charges reduced to the K.W.Hr. basis a
the fixed charges curve; the difference between th
therefore represents the cost of labor, oil and waste, s
and repairs.

The cost of fuel, usually coal, per unit of po
varies with some power of the load factor less than
upon the number and efficiency of units employed b
gine and boiler rooms, also upon the cost per ton of
ing value, and upon the ability of the firemen to get
sults; it is of the utmost importance to watch this i
as greater economy can be secured in the cost of coa
than in any other item of expense. The calorific val
should be tested from time to time and compared wi
of lbs. used per K.W.Hr.

e coal considered is assumed to contain 12,000 B.T.U.'s per
l two curves are plotted in figures 1 and 2 when the cost is
nd $3.00 per ton respectively, the results being added to the



Operating Expenses
of
900 K.W. Condensing Steam Plant - Peak 750 K.W.
Fig. 1

evious curves plotted. These figures of fuel cost per K.W.Hr.
ve the average usually obtained and can only be secured by
t attention in the boiler room; for instance 45% load fac-

tor in the first case 1 K.W.Hr. is generated fro
from the pile.

The ratio of the individual items of expense
expense is shown by figs. 3 and 4 for the conden

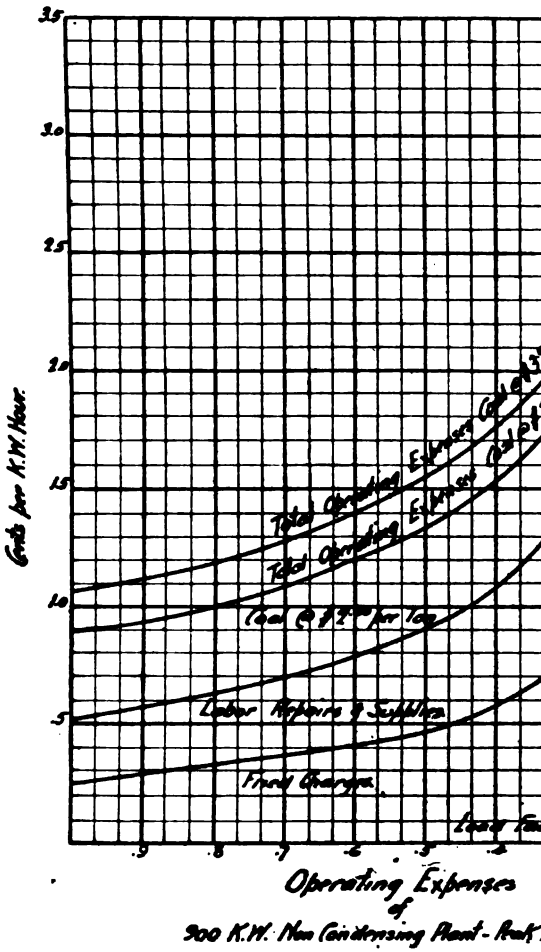
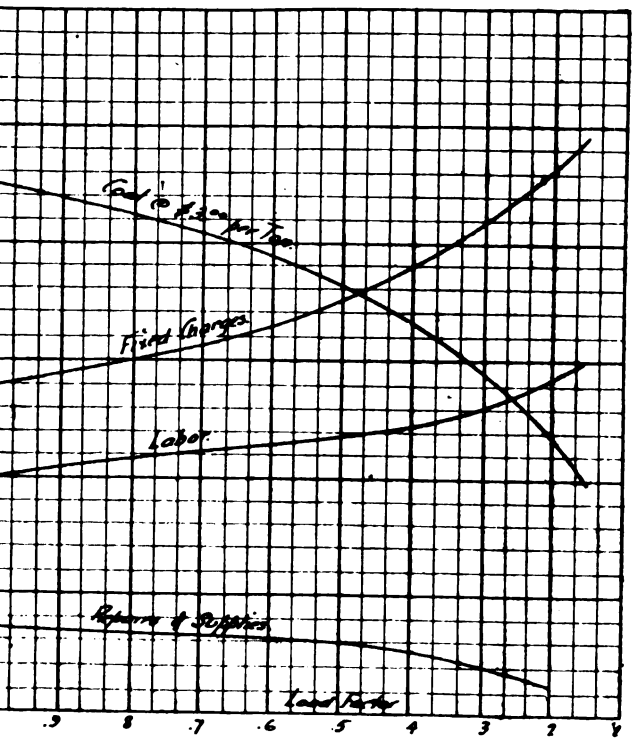


Fig-2

densing plants respectively with coal at $3.00 per
is interesting in this connection to note the high
cost; in the average plant this percentage will b
that shown, but this indicates how great a factor

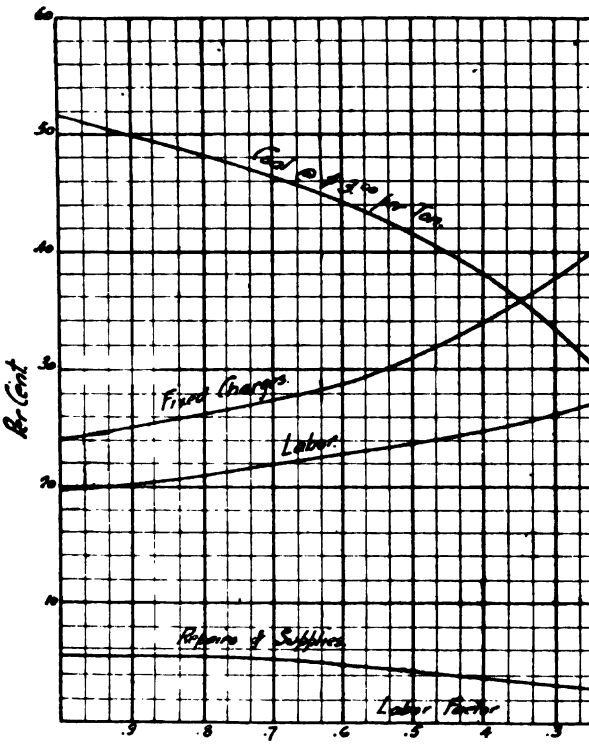
larly with high load factors. For low load factor the fuel is nated by the fixed charges, which is by far the heaviest item. ving thus determined the cost of power for a plant with a 750 K.W., we shall consider briefly a larger plant and ascer- hat extra economies may be secured. This plant we shall to have a peak load of 1,500 K.W. and a maximum capacity



Ratio of Individual Items of Operating Expenses to Total Operating Expenses
500 K.W. Condensing Steam Plant - Peak 750 K.W.
Fig 3

K.W., divided into three units of 600 K.W. each. Stokers d, but no economizers or coal handling apparatus; the boilers a single line parallel to the engine room, and coal is dumped he car into a chute, whence it falls to the floor of the boiler

First cost of this plant at 100% load factor is $241,1 lent to $134.00 per K.W. Fixed charges, using the sa for interest, depreciation, taxes and insurance as in case become $36,318.75 per year. Curves are plotted fixed charges, labor, supplies and repairs, and fuel, the plotted for the two prices $2.00 and $3.00 per ton as be

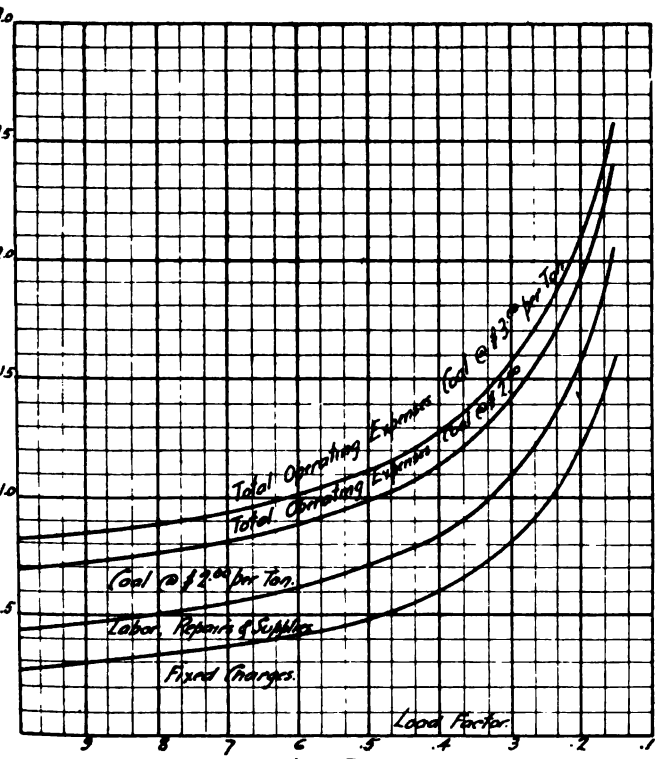


Ratio of Individual Items of Operating Ex to Total Operating Expenses.
900 K.W. Non-Condensing Steam Plant - Belt
Fig - 4

With all these curves before us it might be well to deductions as to the advisability of further expendit power plant in coal handling apparatus and econon general, any apparatus that tends to increase the econ

The higher the load factor the greater becomes t

ıble to fixed charges, and extra investment is advisable to se- the greatest economy possible. Extra investment in coal ling apparatus and economizers will reduce the cost of labor fuel in greater proportion than fixed charges are increased; the omizers also provides greater boiler capacity and purer feed r, reducing cost of repairs.



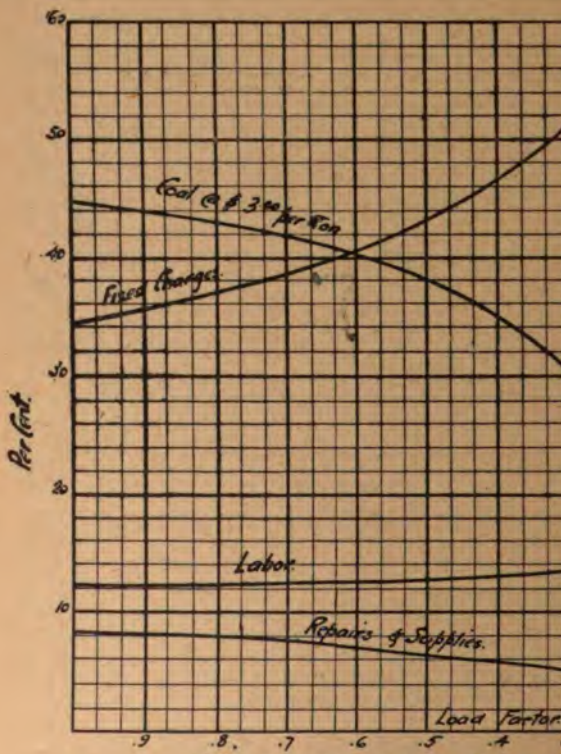
Operating Expenses of 1800 K.W. Condensing Steam Plant- Rat K 1500 K.W.

Fig. 5

On the contrary when the load factor on a system is low, the l charges are the governing factor in the cost of power, and a expenditures must be carefully considered, particularly so if is cheap.

Having thus discussed the effect of load factor on the cost of ducing power, we shall next turn to the cost of management and

distribution. While it is beyond the scope of thi
consider these costs, yet it was thought advisable
curve including all the various costs approximatel
factor influences the cost to the consumer. This
generally, as no two cases are alike; the cost of dis



Ratio of Individual Items of Operatin
to Total Operating Expense.
1800 K.W. Condensing Steam Plant - Peak
Fig-6

variable with different systems than is the cost o
ing on the conditions of distribution, conduit or po
tion and the extent and density of the territory to

We shall allow that $50,000.00 per year covers
maintenance and attendance on the distributing ne
00 per year for management, dividends on stock a

s. For total losses 30% of the output is allowed; this is onstant for all load factors, for while the percentage of losses varies directly with load factor, the percentage of in-nate losses by grounds and theft varies inversely as the load The actual losses from grounds are constant, hence per-loss by grounds varies inversely as load factor; losses from sually occur with customers having a short hour load, and ater the amount of such load connected, the greater this loss. mer having a long hour load runs a greater chance of detec-an others. Hence, the above statement holds that the total age loss will be constant. Further, this lost power reduces ount of sales, therefore affecting all the expenses included in customer.

. 7 shows a series of curves plotted for the 1,800 K.W. steam he lower line representing cost of production, the second, distribution; third, cost of management, and fourth the f distribution losses on cost of power, this last being the st to consumer.

l is expensive, and from the nature of things will increase , and it behooves us to investigate any methods of producing which is more economical in the use of fuel than the steam and naturally turning to the gas engine we will next pro-make a comparison between a steam plant and a gas plant ing producer gas for use in gas engines, and from such com-deduce some general results.

is well-known the gas engine has a very much higher ther-ciency than the steam engine, which fact, together with the umber of auxiliaries required, would naturally lead one to that a greater economy could be secured in the production er.

ficulties, however, are encountered at the outset in the kind that may be used successfully in the gas producer. While s generated from anthracite coal is very successful in the on of gas engines, the gas from bituminous coal contains ch, when carried through the valves into the cylinders of the clogs the valves and carbonises under the intense heat to t is subjected in the cylinder, preventing successful operation. nanufacturers claim to have succeeded in removing the tar enting its formation, but the burden of proof still rests with

e overload rating of the gas engine is different from the engine in the ratio of about 15 to 50 per cent. Hence in de-two plants, steam and gas, for equal overload capacities, it ssary either to use gas engines of 25 to 35 per cent. higher rating, with consequent poorer economy at normal load; or

add an extra engine and generator sufficient
extra overload capacity of the steam engine ov
For example, in designing a gas plant of 900 K.
peak load of 750 K.W., allowing the same reser

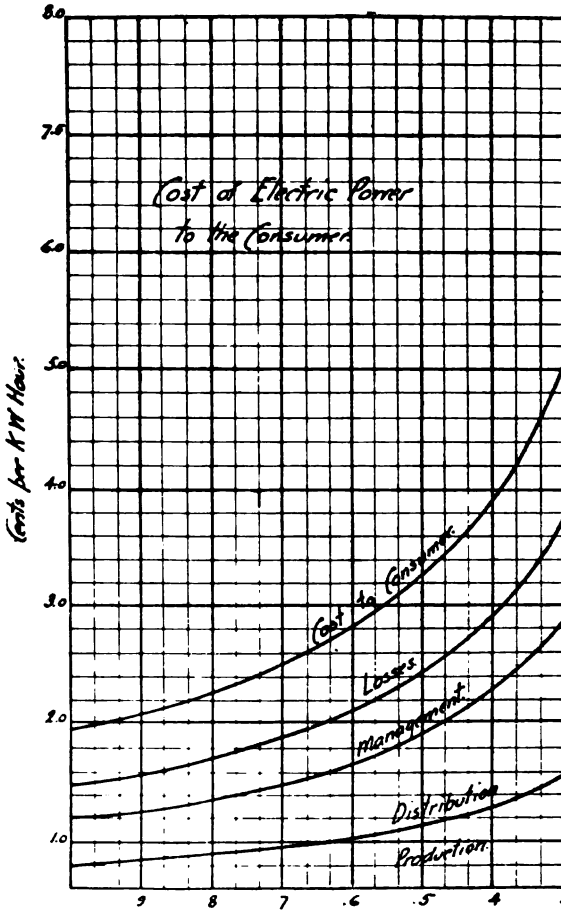


Fig - 7

plant considered previously, three engines of 5
be required with an aggregate normal B.H.P. of
B.H.P. of 1,830, as compared with three 450 I.H.
B.H.P. engines aggregating 1,230 normal B.H.P.

; or three gas engines of 410 B.H.P. each and an additional of 360 B.H.P. aggregating 1,830 B.H.P. on maximum load a practical standpoint, this additional engine would be made

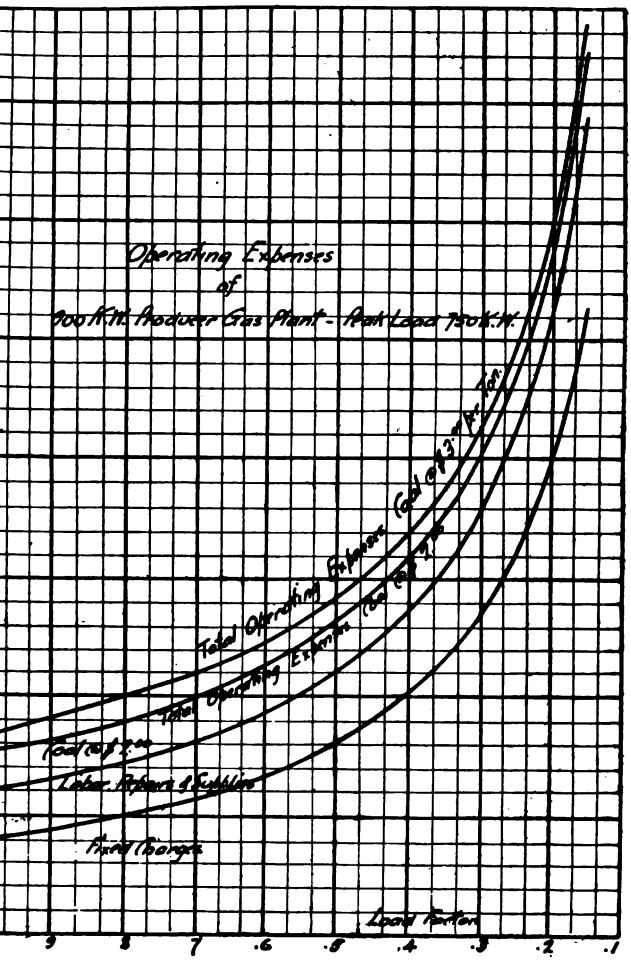


Fig. 8

same capacity as the rest, the cost being the same). In the se at normal load on the generators the engines are 30% oaded with consequent poor efficiency; in the second case st cost will be greater, due to the extra generator and in- size of building required.

Allowing the same reserve capacity in produ
three 530 B.H.P. gas engines direct connected to 3
tors running at 100 r.p.m., the first cost becomes $1
lent to $186.00 per K.W.

Fixed charges:—

Interest at 5% on $167.650.. .. ..
Depreciation on machinery 10%.. .. ..
Depreciation on buildings 3%.. .. ..
Taxes and Insurance 2%.. .. ..

Total.. .. ..

The storage capacity at 100% load factor is sm
cubic ft., and is provided more for uniformity of ga
age. In case of accident to one producer, a secon
way producing gas inside half an hour. The questi
important, particularly at small load factors when
provided for the peak and a constant load maintai
ducers. In a plant of this size where the numbe
actually required is not over two with a third for re
advisable to use the same number of producers for
and a small amount of storage for uniformity of
peaks. Further, the extra storage capacity require
factors costs about the same as an extra producer.

The operating costs for oil, water, repairs, su
have been taken practically the same as for steam
sufficient reliable data at hand on this subject at th

Cost of labor is somewhat cheaper—for the ty
considered only one man is actually required.

In fig. 8 are given curves for cost of power wi
factor for this 900 K.W. gas plant.

A comparison of fig. 1, 2, and 8 shows a great
the gas plant at the higher load factors, but poorer
load factors due to the influence of the heavy fixed

The higher the cost of coal the greater is the
gas over the steam plant at high load factors.

It must be remembered that the fuel economy
the steam plants is taken considerably higher than
can only be secured by constant and careful atte
details around a power plant; in the gas plant the
factor is taken at 1.4 lbs. coal per B.H.P.Hour, wh
higher than the manufacturers will guarantee. No
fuel costs may vary from those given in the
are relatively of far greater importance when the lo
than when it is low.

ER No. 222.

: ELECTRO-THERMIC PRODUCTION OF IRON AND STEEL.

By EUGENE HAANEL, Ph.D.

The iron and steel industry is the foundation of all other stries. To develop the former furnishes the means and in-ve for the development of the latter. A country which re-s to import its iron—the raw material for all industrial pro-—is severely handicapped in the race for commercial success. only when a country is able to manufacture commodities be-its need that exportation and expansion of trade become ble.

During the year 1903-1904 (Trade Navigation Report) Canada rted:—

iron, steel ingots, ferros, scrap, etc.	1,727,867
, bars and other manufactured iron and steel	12,172,082
t iron and plates	5,223,250
s	2,216,413
lware	4,593,226
cultural and miscellaneous machinery	17,178,761
Total	$43,111,599
To ascertain sale value add 25%	$10,777,899
	$53,889,498

ese figures show to what extent we are at present dependent outside sources for iron in the crude and manufactured state. influx of settlers requiring tools and machinery, the building ew railroads, the displacement of wood by steel in modern itecture, the multiplication of established, and the inaugura-of new industries will, in the near future, rapidly increase e the present demand the annual quantity of iron and steel ired for home consumption. To stimulate and encourage the uction of iron and steel for our abundant sources of raw erial the Government has offered generous bounties on pig and produced in Canada, and placed an import duty on articles ufactured from iron and steel. Regarding the distribution of

the raw material for the prouction of pig, the conditions of the country are, however, such that the necessary coking coal for blast furnace work is found only at the extreme east and west, while the large Provinces of Ontario and Quebec, possessing numerous and extensive deposits of iron ore, are without coal deposits. If these deposits are to be utilized in the production of pig by the present method of smelting, either coke must be brought to blast furnaces erected in the vicinity of these deposits, or the ore of these Provinces must be transported to blast furnaces erected near an abundant coal supply. In either case the transportation costs render such a course uneconomic. Unless some other method of smelting, in which some other source of energy than that resulting from the combustion of carbon in blast furnaces, can be proven to be practical and economic, the extensive ore deposits of these provinces will remain to a large extent undeveloped, and regions which might otherwise be made to teem with an industrial population, will remain waste areas for many years to come.

The necessity of profitably employing the electric plants erected in different parts on the Continent, especially in France, for the production of carbide, which had to be closed down as unprofitable on account of over-production, furnished the incentive to invent methods for applying electric energy; first,, to the production of the different ferros, and subsequently to the the production of pig and steel.

In the solution of the problem of applying electric energy to the extraction of metals from their ores, Captain Stassano in Italy, and Heroult and Keller in France, have rendered conspicuous service. The description of the experiments made by them and the results obtained attracted wide attention and were eagerly discussed in the scientific press, for it was at once seen that if by the electric process pig could be economically produced, such countries as Brazil, Chili, Sweden, Norway, Finland, and our own two provinces of Ontario and Quebec, all rich in iron ore deposits and the necessary fluxes, and possessing extensive water powers but lacking coal, would be able to render themselves independent of outside sources by employing the electro-thermic process for the manufacture of their iron and steel.

It was with a view of ascertaining the feasibility of introducing electric smelting into Canada, that the Honourable the Minister of the Interior appointed two separate Commissions to investigate this subject.

For a number of years the Ruthenburg process of electric smelting of magnetite had attracted attention. Papers on the subject were read by the inventor of the process in the meetings of the Electro-chemical Society, were seriously discussed by the

RUTHENBURG **FURNACE.**

of the society and published in their transactions, which his process a quasi scientific sanction. No examination made of the process by any competent authority, and had been published so far had been published on the of the inventor of the process. It seemed, therefore, that the claims of the inventor, which were rather start-ding the efficiency of his process, should be investigated run, and a Commission was appointed on the 2nd July, the Honourable the Minister of the Interior, consisting vernment Electrician, Mr. Higman, the Metallurgist, Mr. d myself, with instructions to proceed to Lockport, N.Y., Ruthenburg electric furnace had been set up in the ectric Smelting and Aluminum Works, and investigate ncy of his process.

ond Commission was appointed on December 28th, 1903, l to Europe and investigate the different electro-thermic for the smelting of iron and the making of steel in oper-Europe. This Commission consisted of Mr. C. E. Brown, n; F. W. Harbord, Metallurgist; Mr. Nystrom, Drafts-Cote, Secretary, and myself.

ving a short epitome of the work done by these two ons I will give, with your permission, the facts elicited ler of the appointment of the Commissions.

IE RUTHENBERG PROCESS OF ELECTRIC SMELTING OF MAGNETITE.

Description of Furnace.

urnace consists of an electro-magnet (horse-shoe pat-cast-iron, with pole-pieces of soft steel. The two limbs agnet are electrically insulated from each other at the ich, in the form of a joint, permits the variation of the een the poles by means of a screw. The limbs of the re surrounded for nearly their entire length by closed ms, which are provided at the end farthest from the h means for rotating them towards the gap. The rota-fected by a separate motor of about ¼ horse-power. ums serve the double purpose of absorbing by water cir-through them the heat generated and of giving motion e toward the gap. The parts of the drums to which the current is distributed and which forms the electrodes l with carbon plates. The current was furnished by two rect Current generators, joined in series of 50 volts and peres capacity each, thus giving 100 volts and 3,000

A Weston ammeter of 4,000 amperes capacity, a Weston voltmeter, reading to 120 volts, and a Scheefer recording wattmeter, No. 42,203, specially constructed for 2,000 amperes at 110 volts, were in circuit with the main current.

Description of the Process.

The magnetite is first coarse-crushed and sent through Cornish rollers for fine crushing. From these it passes into magnetic separators, which eliminate the non-magnetic constituents. The resulting concentrates are mixed with carbon in amount somewhat in excess of the amount needed to reduce the ore to the metallic condition. Partial reduction of the ore is expected to be effected by the working current in the gap of the carbon-covered drums, where, on account of the magnetic field, the mixture of ore and carbon forms a bridge, the carbon being held in place by the magnetite threads which span the gap. The partially reduced ore in the heated condition loses its magnetism and drops into a cooling pit, being replaced by a fresh mixture of ore and carbon; the process is thus automatic and continuous.

The partially reduced and heated ore is expected to agglomerate into masses in the pit, where it is assumed to undergo further reduction. After the cooling, the fritted mass is, according to the patentee's account, melted in a cupola and cast into ingots, or directly transferred to an open hearth furnace and converted into steel.

Calibration of the Electric Measuring Instruments.

The calibration of these measuring instruments was undertaken by Mr. Higman, who employed for this purpose his own official standards. The Weston ammeter and voltmeter were found to be correct, but the wattmeter failed to record. Examination by the agent of the firm in St. Catharines revealed the fact that the lower ball-bearing of the spindle of the rotating disc was missing, and that the connection of the potential coil had been broken.

The wattmeter being of special design and not kept in stock, it became necessary to send it back to the factory in Peoria, Illinois. To avoid all unnecessary delay, Mr. Higman undertook to convey it to the factory and personally supervise its refitting.

Determination of Electric Energy Absorbed.

On the return of Mr. Higman with the repaired and calibrated wattmeter, it was decided to make a trial run of a quantity of

ient to determine the electric horse-power absorbed in the per ton of product. The following mixture was employed uthenburg for this purpose:—

Moisie Iron Sands	3,200 lbs.
Sawdust..	200 "
Coke, crushed	800 "
Total	4,200 lbs.

re conveying this mixture to the bin, which was situated nd above the furnace and supplied the furnace by means ut, the patentee plentifully sprinkled the charge with a pot, in the hope that the water would bind the in- of the mixture sufficiently to prevent their separation in according to their specific gravities. This naturally im- e additional useless burden upon the furnace of provid- ient heat for the evaporation of such water.

tarting the furnace it was found that the resistance in the so great, that with the available pressure of 100 volts ut 150 amperes, on an average, could be driven through bridge in the gap, and even when the gap was narrowed an inch, the current could not materially be increased. ven feeding and the uneven size of the particles of the caused the resistance in the gap to vary to such an extent ammeter indications fluctuated rapidly througout the ex- s 50 or even 0 and 200 amperes. Unfortunately the disc ecording wattmeter remained stationary whenever the strength fell below 150 amperes. From this it is evident wattmeter readings, as recorded by Mr. Higman, did not t the whole electric energy absorbed. As the experiment ed, it was found that the sawdust of the mixture was tially acted on in the gap, particles passing through with- ng been carbonized, and the large pieces of coke, heated ght redness by the current, absorbed the electric energy any useful return in effecting the reduction of the ore. sands and coke particles fell in a fine, fiery rain into the re they rapidly cooled, the iron sands having lost their sm before incipient fusion had set in, the product of the in the pit failed to agglomerate into masses, and consisted ly of nearly the same physical and chemical constituents re mixture employed. After a period of 17 hours and 37 it was, therefore, thought a waste of time to continue the hough a considerable quantity of the charge still remained

surrounding the throat of the furnace, were charged into the furnace by hand labour. The waste gases were allowed to escape and burn at the top of the furnace.

The composition of the charge in the first set of experiments consisted of:—

Ore..	500	kilograms,
Coke.	100	"
Lime	60	"
Quartz..	30	"

The resulting iron was very grey, containing considerable of both silicon and manganese. The coke was, therefore, reduced to 90 kilograms, the lime to 30, the quartz to 10, and still later the quartz was entirely omitted. The iron was low in phosphorus and sulphur.

Tappings occurred every two hours, and the molten metal was run into clay lined, horizontal, cast iron moulds. The length of run was 55 hours. Amount of pig produced was 9,868 kilograms.

The furnace worked quietly throughout the experiments, and without the slightest accident, although the current reached 12,000 amperes in one set of experiments. The carbon monoxide burned on top of the furnace in flickering flames, showing that the gas resulting from the reduction of the ore escaped without pressure. The workmen were ordinary Italian labourers, without any special training.

The electric energy expended per ton of pig in these experiments was .475 horse power years.

In a second set of experiments the charge had the following constitution:—

Ore	525	kilograms.
Coke.	95	"
Lime..	15	"

This was, towards the close, altered to:—

Ore..	500	kilograms.
Coke	102.5	"
Lime..	25	"

The electric energy expended was 0.226 horse power years per ton of pig. The length of run was 48 hours. Amount of pig produced was 6,692 kilograms.

For the first set of experiments the alternator furnishing the current was a revolving field machine with 16 poles, and rotating at approximately 380 revolutions per minute, with a periodicity of

s per second, and was direct connected to a horizontal shaft heel controlled by a governor. Mean voltage 59.1.

the second set of experiments the alternator employed was at about 280 revolutions per minute, giving a periodicity cles per second. Mean voltage 55.3.

scertaining the electric energy absorbed when an alter- urrent is employed the volt-amperes read from the switch- istruments do not furnish the watts delivered, since, on of the reactance of the circuit, the amperes are not in ith the volts, but lag behind the volts. It is, therefore, to determine the cosine of the angle of lag, or, as it is e expressed, the power factor must be ascertained, that gure by which the volt-amperes require to be multiplied to furnish the watts delivered. This determination was r us by the Director of the Electrotechnical Institute of the ty of Grenoble for the two machines employed in furnish- current for the two separate sets of experiments. The r and ammeter in circuit with the furnaces were also d by the same high authority.

ender ourselves independent of the switch-board instru- n the determination of the electric energy absorbed, a on recording wattmeter, rented from the Compagnie pour cation des Compteurs, Paris, and calibrated by them, was ted in the circuit, although this necessitated the cutting eavy copper bars carrying the current, and greatly incon- d the firm who were good enough to go to the trouble and pense of making these experiments for us.

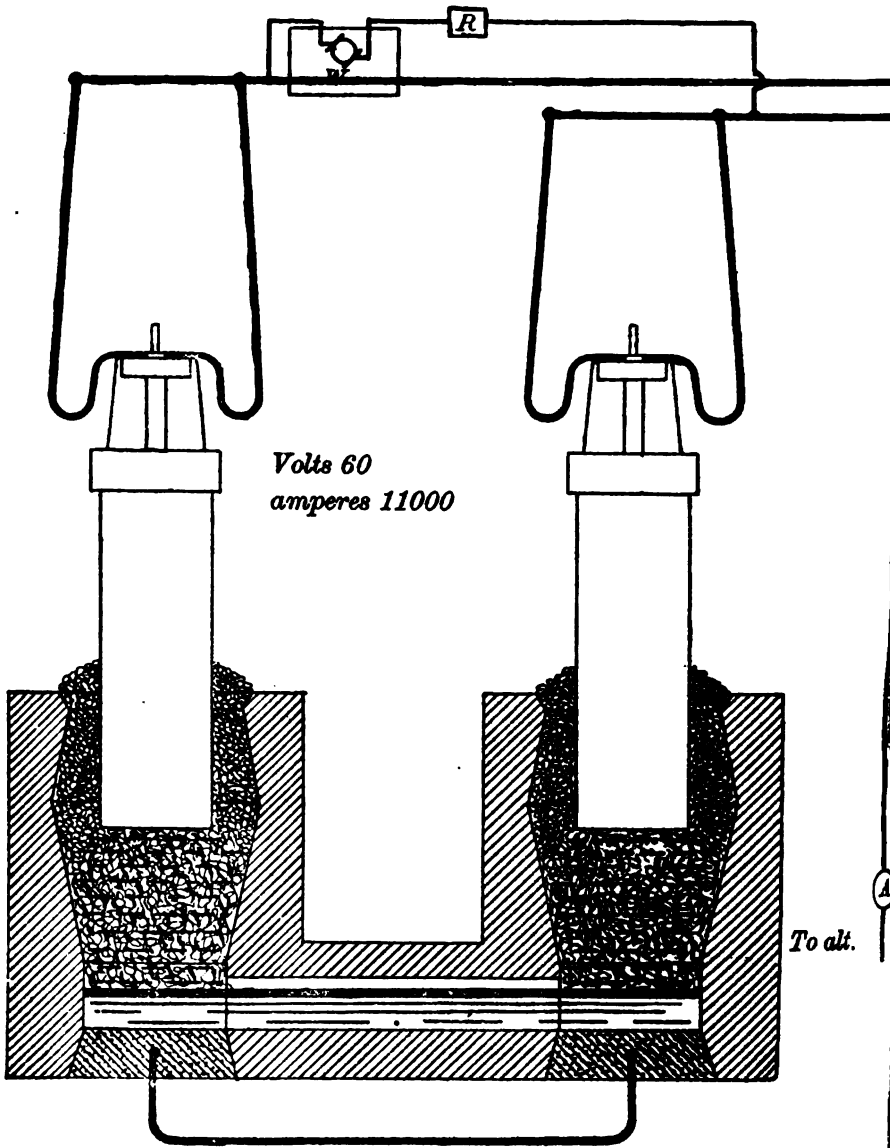
Quality and Kind of Pig Iron Produced.

adjusting the charge it was easy to obtain any grade of pig ired, grey, white or mottled, and castings were made direct e molten metal of the furnace, such as columns, gear plates, etc., all showing sharp edges and comparatively surfaces.

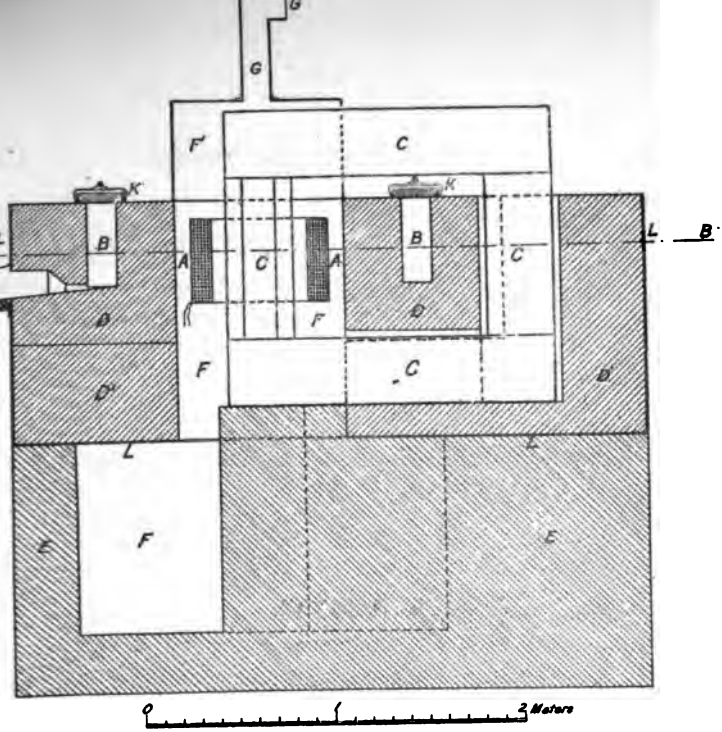
Cost of Production of Pig by Keller Process.

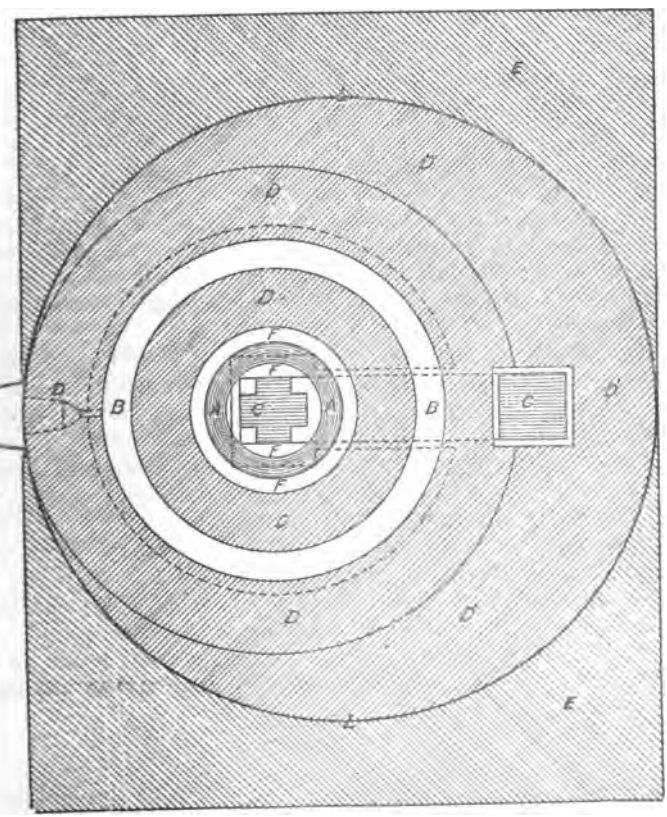
Keller's estimate of cost per ton of product, based on the consumed in the second experiment and found to be 0.226 horse power years, is as follows:—

(Hematite, 55% iron) 1,842 tons @ $1.50 per ton ..	$ 2.76
e, 0.34 tons @ $7.00 per ton	2.38
sumption of electrodes, $45.00 per ton, 34 lbs. per ton of iron	0.77
e, 300 lbs. at $2.00 per ton..	0.30



KELLER FURNACE.





KJELLIN FURNACE.

5. Labor at $1.50 per day .. ..
6. Electric energy 0.226 h.p. years at $10 per h
7. Miscellaneous materials.. .. ..
8. Repairs and maintenance .. ..
9. General expenses... .. ..
10. Amortization (machinery and buildings).. .

Total, exclusive of Royalty.. .. .. .

Mr. Harbord has furnished reasons for assu
the determination of the two sets of experiment
E.H.P. years, to be a safer figure on which to b
of cost per ton of pig produced. With this cha
of E.H.P. and 100 lbs. additional of lime, the c
is $12.05.

Regarding these costs I desire to make the f

On account of the construction of the Keller
short shaft, the utilization for reduction of the
evolved has been very small, only 19.5% of the
bon theoretically necessary for the reactions eff
as carbon monoxide. By increasing the length o
viding the upper part of the furnace with gas coll
pose of utilizing the escaping gases for the prelim
charge the electric energy required would be con
Moreover, instead of employing the costly coke,
coke might be employed. Experiments were ma
request, substituting charcoal for coke, but prov
reason for this failure is easily found in the fa
charcoal coming in contact at the throat of the
burning carbon monoxide was readily consumed
condensed in its pores, as well as by the oxygen
surrounding it.

If the charcoal had been briquetted to reduc
gas absorbing power and the shaft of the furnac
cient length to discharge the resulting carbon
ignition temperature, charcoal, which can be
tured from mill refuse, but which is useless in
could readily be substituted for the coke now em

Regarding the cost of electric energy in thi
been credibly informed that an electric horse p
furnished by the development of the Chats Fall
doubtedly many water powers will be found, fav
regards ore supply, which can be developed as cl

If then in our estimate of cost we substitute
tric Horse Power year and $4.00 per ton of briq

oke and allow for the saving in electric energy by a more mic use of the carbon monoxide produced in the furnace to nstructed with longer shafts and provided with appliances for g the furnace gases, we would arrive at a very economic figure ich pig can be produced, something like $9.28 per ton.

desire here to emphasize that every step in the experi- made at Livet has, as far as practicable, been carefully ed.

HIRD—MANUFACTURE OF STEEL BY THE GYSINGE PROCESS.

t the Gysinge works in Sweden steel of a superior quality is in electric furnace of the induction type.

Description of the Furnace.

he furnace consists of a cylindrical iron casing partly closed base, resting upon a brick foundation. The casing is lined fire brick and that part which contains the annular groove is in with magnesite or silica brick, according as a basic or acid is required for the groove which forms the melting space or ole. In the centre, and coaxial with the annular crucible the ry is placed, to which is distributed an alternating current of peres at 3,000 volts, which induces in the secondary formed e metal in the annular crucible a current of 3,000 amperes olts. The conversion of electric energy into heat takes place, ore, in the substance which fills the annular crucible.

Process.

he process, as carried out at Gysinge, consists in melting to- r Dannemora charcoal-pig and Walloon scrap in such propor- as will insure the proper carbon content in the steel produced. he following is the composition of the charge for the steel ir usual manufacture:—

White pig iron..	300 Kgs.	—C. 4.40 %
Steel scrap..	125 "	S. 0.015%
Bar scrap	600 "	P. 0.018%
Metal in furnace	700 "	—C. 0.2 %
Silicon pig	30 "	S. 0.003%
Ferro-Manganese	1 "	P. 0.009%
	1,756 Kgs.	

The crucible is never emptied completely, but about 700 kgs. are left in it at each tapping to maintain the current.

The time required for melting down this charge and getting it to the proper temperature is six hours, when it is tapped into ladles and teemed into iron moulds. The electric energy required per ton of product is 0.116 E.H.P. years.

Experiments Made.

Three different grades of steel were made for the Commission:

1st: The regular steel with carbon content of 1%, for which the furnace had been specially designed. Electric energy required per ton 0.116 E.H.P. years.

2nd: A steel containing about 0.5% of carbon, which was obtained without difficulty, but at a greater expense of electric energy. The electric energy per ton required for this steel was 0.145 E.H.P. years.

3rd: A very mild steel containing about 0.1% of carbon. This grade of steel was produced with considerable difficulty. The electric power necessary to bring the contents of the crucible up to the proper tapping heat was not available.

Quality of the Steel.

The experiments made with the Gysinge steel containing 1% of carbon at the Woolwich Arsenal proved the steel to be equal to the best crucible steel manufactured.

Electrical Measurements.

In order to be independent of the switch-board instruments for the measurement of the electrical energy absorbed in the manufacture of steel at Gysinge, standard volt and ammeters and a wattmeter were rented in Stockholm and placed in circuit.

The electric current delivered to the furnace is obtained from a single-phase revolving field alternator, rated at 3,000 volts and 90 amperes. It is a 24 pole machine with a speed of about 75 revolutions per minute, giving a periodicity of 15 cycles per second. It is arranged with a vertical shaft direct connected to a water wheel.

The low power factor (average of first run 0.672) and the low periodicity of the alternator are disadvantages which are inherent to the system employed, but the fact that the furnace takes current directly at a voltage suitable for generation and transmission over moderate distances, requiring neither carbon, special connections, nor electrodes, with their attendant cost, loss of power and necessity of attention, is an important advantage.

Cost of the Steel Produced.

Materials	$31.66
Wages..	2.66
Renewals and repairs...	0.60
Electric energy..	1.48
Ingot moulds	0.48
Interest and redemption	0.60
Per metric ton	$37.48

or $34.00 per ton of 2,000 lbs.

General Remarks.

The process as practiced at Gysinge with the present construc- of the Kjellin furnace does not permit the purification of the erials employed. The quality of the steel depends entirely the purity of the component materials employed. On the r hand this process is especially adapted for the manufacture igh grade carbon steels and high speed steels, such as tungsten molybdenum steels. The heat is generated within the material lf, and not subjected to absorption of gases nor impurities from trodes.

The capacity of the furnace at present employed is small, the out being a little over four tons per 24 hours. For a larger t, Mr. Kjellin proposes that three furnaces of 15 tons capacity of the pattern now used be united into a compound furnace, separate furnace surrounding a leg of a three phase trans- ner and made common in the centre.

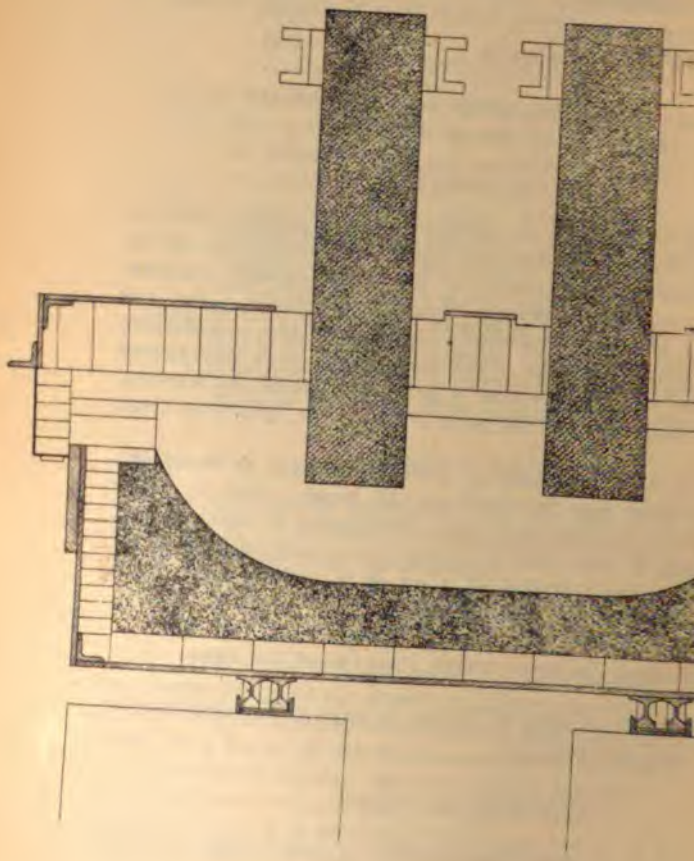
FOURTH—THE HEROULT STEEL PROCESS AT LA PRAZ.

At La Praz steel of different grades is made from miscellaneous p by the Heroult Process.

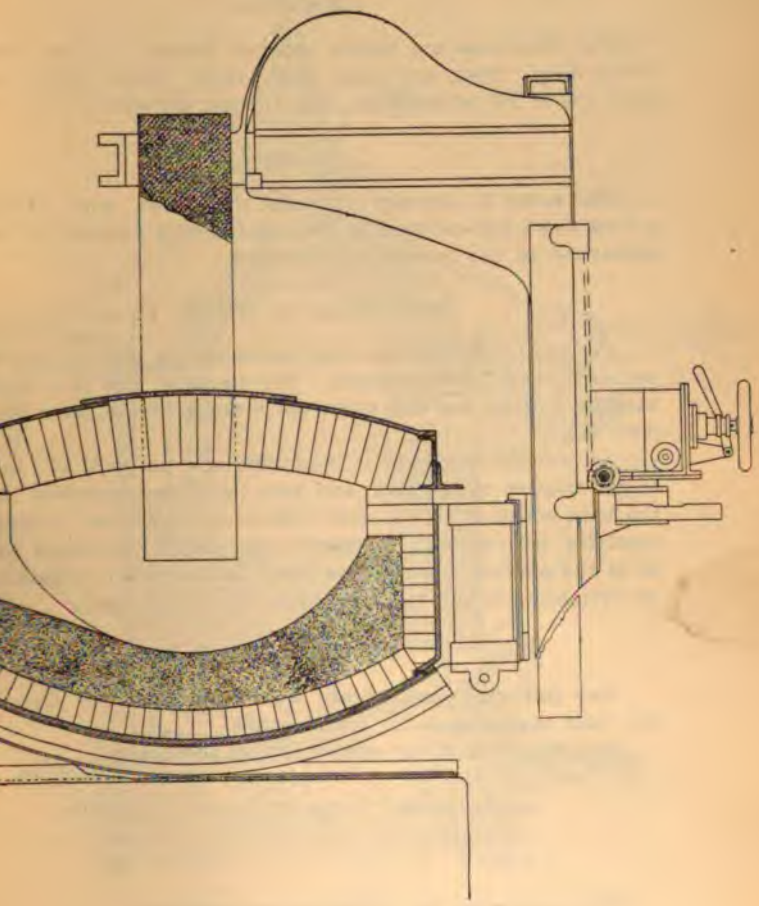
Description of Furnace.

The furnace is of the tilting pattern, in shape much like the ing Campbell furnace.

It consists of iron casing lined with dolomite brick and mag- ite brick around the openings. The hearth is formed of crushed omite, rammed on top of the dolomite brick-lining of the bot- of the iron casing. Two electrodes pass through the roof of furnace, which, in the Kortfors furnace, were water jacketed a short distance above and below their passage through the casing of the roof. The current passes from one electrode



HEROULT FURNACE



HEROULT FURNACE.

through the narrow air gap left between the electrodes and the slag line, into and through the slag to the molten metal, along it, through the slag and the second air gap, to the other electrode.

Electrodes.

The electrodes are square prisms 360mm. on the side and 170cm. long. They are made from retort coke which contains from 1% to 2% of sulphur. The binding material is tar.

Process.

The scrap is charged through the doors with some lime melted down and purified by the making of a number of slags and carburized in the furnace by carburite.

Measurement of Electric Energy.

The electrical readings were taken on the regular switch-board voltmeter and kilowatt-meter. No ammeter was in circuit. The average voltage was 110 volts, the mean kilowatts, full gate open, were 340.

An automatic regulator controlled the position of the electrodes relative to the bath, and kept the voltage between them and the bath constant. Two volts difference either way brought the regulator into action. Whenever the current fluctuated violently, as in the melting down of the scrap, the automatic regulator could be switched out and the regulation effected by hand.

Experiments Made.

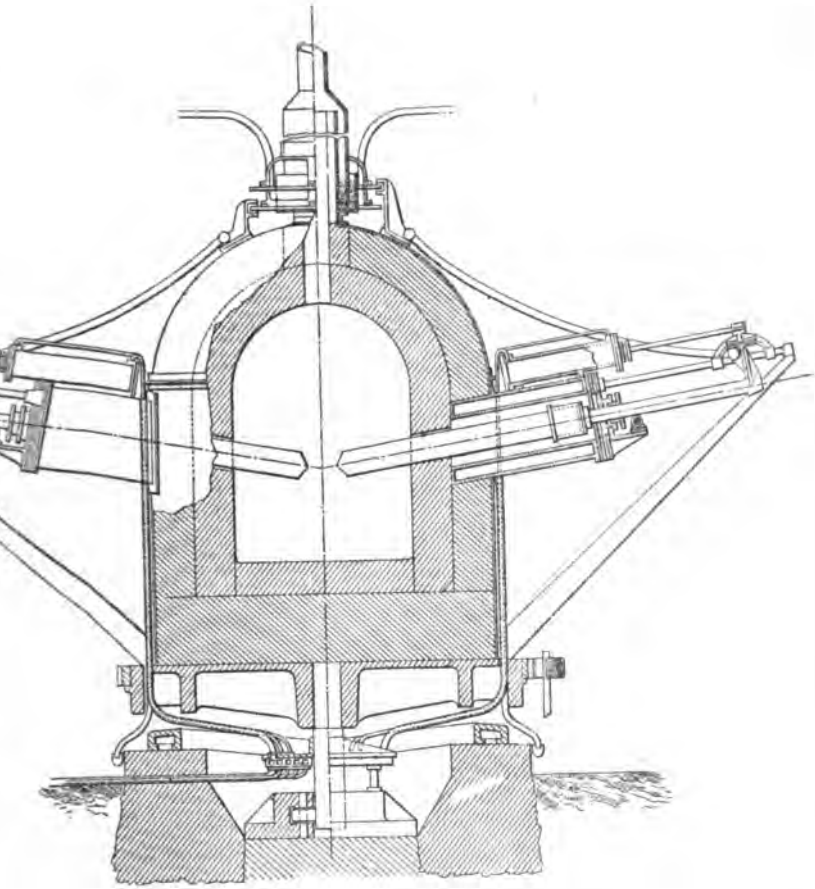
The following experiments were made for the Commission: 1st: Low carbon steel for transformers.

The following is the composition of the charge:

Miscellaneous scrap	3,307 lbs.
Iron ore	330 "
Lime..	246 "

The scrap had the following composition:—

C. = 0.110		C. = 0.079
Si. = 0.152		Si. = 0.034
S. = 0.055		S. = 0.022
P. = 0.220	Steel produced.	P. = 0.009
Mn. = 0.130		Mn. = 0.230
As. = 0.089		As. = 0.096



STASSANO FURNACE.

When metal and slag had been completely melted the slag was poured off, great care being taken to ensure the complete removal of the slag. A new slag was then made by adding 55 lbs. of lime, 15.5 of sand and 15.5 lbs. of fluorspar. This was melted and kept in the furnace for some time. It was then poured off, and the last traces of it raked off from the surface through the pouring door.

A third slag of similar composition was then made as a finishing slag to remove the last traces of impurity, and then poured off. 1.5 lbs. of ferro-manganese were added and the charge was poured into a ladle and a little aluminum thrown in before the metal was teemed into ingot moulds.

On account of the smallness of this charge the time for working was only four and half hours, and since the product was low in carbon no time was required for re-carburization. The steel, when teemed, ran freely from the ladle, leaving no appreciable scrap. It was quiet in the moulds, and the ingots were exceptionally sound for steel of this quality.

The yield was:—

2,820 lbs. ingot.
9 " scrap.

The electric energy consumed was 0.153 E.H.P. years per ton of steel produced.

2nd: High carbon steel.

The charge for this grade of steel consisted of:—

Miscellaneous scrap	5,733	lbs.
Ferro-silicon..	19	"
Iron ore	430	"
Lime.	346	"
Ferro-manganese	3.3	"

The purification was effected as before by the making of three slags, and required five hours and twenty minutes. If soft steel had been required, the furnace would have been ready to tap at this time. The metal, however, required to be re-carburized to the required point, and this was effected by adding to it in the furnace "carburite," a mixture of pure iron and carbon. 19 lbs. of 13% ferro-silicon were added at the same time. The charge was sampled in the usual way with a spoon ladle, and when the furnace man was satisfied that the bath contained the required amount of carbon, the metal was poured into the ladle, a little aluminum added and teemed into ingot moulds. The metal ran very freely, leaving no skull in the ladle, was quiet in the ingot moulds, and forged extremely well.

Composition of the Steel Produced.

C.	1.016
Si.	0.103
S.	0.020
P.	0.009
Mn.	0.150
As.	0.060

for working, 8 hours.
ic energy consumed, 0.153 E.H.P. years per ton of steel pro-

the metal had been tapped before re-carburization the elec-
ıergy consumed would have been 0.1 E.H.P. year per ton.

Quality of the Steel.

ıese steels have been examined for us regarding their wear-
alities as tool steel by the officers of the Woolwich Arsenal
onounced to be equal to the best crucible steels.
nay here mention that for lathe tools in large machine
crucible steel is no longer employed as tool steel; Tungsten
olybdenum steels, or what are termed high speed steels,
exclusively used for lathe, planer and similar tools.
ere is no difficulty of producing these steels by the Heroult
s, ferro-tungsten or ferro-molybdenum need only be added
ropriate amounts before casting.

Cost per Ton of Product.

Raw scrap	$12.00
Electrodes	.20
Electric energy	1.53
Repairs and renewals	1.40
Labor	1.86

e capacity of the Heroult furnace described is small, about
ons in 24 hours; this has been increased to seven tons by
dition of water-jackets around the electrodes, but without
g the design of the furnace, its capacity could readily be in-
l to 15 tons.

H—THE DIRECT MANUFACTURE OF STEEL BY THE STASSANO PROCESS.

ut carbon into iron in the production of pig and take it out
by a second process in the manufacture of steel appeared to
n Stassano an irrational and uneconomic proceeding, and he

devised, therefore, a method for making all grades of iron and steel direct by one operation. For this purpose the quantities of ore, flux and carbon are calculated out to furnish by reaction the class of iron and steel required, briquetted and subjected to the heat of the electric arc in his furnace.

Description of Furnace.

The furnace is of the arc type, and consists of a cylindrical outer casing of iron surmounted by a conical roof. The furnace is lined with formed magnesite brick. The axis of the furnace is inclined to the vertical by a small angle, and during the operation of smelting the furnace rotates about its axis, thus agitating the charge and bringing constantly new material to the surface to be subjected to the radiation of heat from the arc, which assists greatly the reactions which require to take place in the reduction of the ore.

A three-phase alternating current of 90 volts between the phases and 400 amperes is distributed to the three electrodes which nearly meet in the centre of the interior of the furnace. Their distance apart is varied, as required, by a hydraulic regulator.

Since nothing is present except heat and the materials which enter into the charge, the calculations and results should agree. This Captain Stassano has demonstrated to be really the case by an elaborate set of experiments, and on the table before you are one of his briquettes and some samples of steel made by his process in one operation direct from the ore.

The Commission has unfortunately not been able to make a trial run and determine experimentally the figures which enter into a determination of the cost of product by his process, since his furnace was out of repair, the roof lining having fallen in and the refractory bricks ordered from Austria for repair not having arrived. And while I cannot, therefore, speak with authority about the efficiency of his process, we need to be reminded that a metallurgical process, which appears to be more simple than another process, is not, therefore, necessarily the more economic. The following are some points which occur to me, regarding this process, which would militate against the economy:—

1st: On account of the position of the source of heat above the charge, the reduction of the ore requires to be performed by the solid particles of carbon, producing carbon monoxide. This carbon monoxide so formed can take no further action in the reduction of the ore, since at the temperature within the furnace carbon dioxide could not be formed, and hence the reducing power of the carbon monoxide, which must escape as such at the throat of the

rnace, is not alone not utilized, but the gas escapes at a high mperature, which entails great loss of heat. The electric energy quired for reduction will, therefore, in this class of furnace ex-ed that required in furnaces which permit the heated carbon onoxide to rise through a column of the charge of sufficient ight to utilize a minimum of its reducing power.

2nd: The process is discontinuous, the charging requiring to done through side doors beneath the electrodes, after tapping slag and metal.

3rd: On account of the construction the capacity of the furnace l not exceed 10 tons of product.

With respect to the economy of this process, Dr. Hans Gold-mmidt, who has investigated the process, expresses himself to me his letter of March 8th in the following words:—

"A method which would enable us to produce steel directly m the ores by means of the electric process has not been rked out and tested sufficiently so as to be able to erect exten-e plants without undue risk."

General Remarks.

The modern blast furnace and the different methods for the king of steel, as at present employed, are the results of a hun-d years of experience, and have reached their present perfec-n through many modifications, which in many instances were epted and introduced into practice only after much hesitation l opposition. The electro-metallurgy of iron and steel is of y recent date, and although high class steel has been commer-lly produced and put upon the market for a number of years, plant as yet exists where iron ore is commercially reduced to by the electric process.

But when we consider that the experiments made at Livet were de in furnaces not at all designed for the production of pig, and nished a figure of cost which permits comparison with the cost pig iron produced by the highly developed metallurgical appli-es, the blast furnace, we have every reason to expect that the ctro-thermic process for the production of pig will be success-ly introduced in regions where water power can be developed aply in the immediate neighborhood of extensive iron deposits. en it is further understood that the electric process is applic-e also to the smelting of ores, such as copper, nickel, etc., that furnaces are of simple construction, the temperature available 00° above that of the blast furnace, and the regulation of the t supply under perfect control, we may expect that the near ure will witness great strides in the application of electric

energy to the extraction of metal from its ores, and that familiarity with handling large currents, and experience gained in electric smelting will result in solving the difficulties encountered in the smelting of ores, which up to the present time have proven refractory to all economic processes known. I need only mention that the treatment of the highly titaniferous iron ores, of which enormous deposits exist, have resisted successful treatment by the blast furnace method of smelting. Mr. A. H. Allen, of Sheffield, who has made experiments in this direction, states:—"That by making a highly acid slag it was possible to smelt such ores, though resulting in the wear and tear and detriment of the blast furnace, and of the blast furnace manager."

Mr. Keller, of Livet, however, has shown that the New Zealand iron sands, which contain 9.3% of titanic acid, can be treated with perfect success in the electric furnace by the employment of an ultra-basic slag and extreme hot working. The slag took up the whole of the titanic acid, and was found on analysis to contain 14% of it. Of course, such ultra-basic slag, on account of its high melting point, could not be rendered fluid with the temperature available in the blast furnace.

Regarding the conclusion arrived at by Mr. Harbord, the Metallurgist of the Commission: that at present structural steel to compete with the Siemens or Bessemer steel cannot be economically produced in the electric furnaces, and such furnaces can be used commercially for the production of only very high class steel for special purposes, it is important that the emphasis be placed on the words "at present." His conclusion is based upon the furnaces examined by us, the capacity of which was small, as it always is with appliances for the exploitation of new processes, but there is nothing inherent in the nature of electric furnaces which would prevent their being constructed of sufficient size to have a capacity equal to the Siemens open hearth furnace, and the engineering difficulties which may present themselves in arriving at a modification of design necessary for such increase of capacity are not likely to be found insuperable. We need only look back in the history of metallurgical appliances to note in almost every instance the gradual increase in capacity from a very small output at the beginning.

Thus, the size of blast burnaces toward the close of the 16th century permitted only an output of three-quarters of a ton per day of 24 hours. This increased in 1,800 to 3.3 tons per day and iron men of that day would have though it incredible, perhaps impossible, to increase, as is now done, the capacity of the blast furnace to 500 tons per day.

Again, 30 years ago 30 tons of copper per 24 hours was re-

as fair duty for a copper furnace; to-day such furnaces daily capacity of some 300 tons. The original Siemens rth furnaces (1868) had a capacity of only three or four odern furnaces have a capacity of 40 to 50 tons.

iew of this, who is to say that structural steel cannot be electric furnaces simply because the present furnaces have, ural in all beginnings, a small capacity.

e is no question in my mind that we are on the eve of hievements as regards the application of electric energy to ction of metals from their ores and that the energy of the abundant, and as yet undeveloped water powers of Can- ere long be employed for metallurgical purposes.

MINING SECTION.

President—J. B. PORTER.
Vice-President—K. W. BLACKWELL.

A meeting was held Thursday, February 9th, 1905, Dr. J. B. Porter in the chair. The following paper was read:—

PAPER No. 223.

THE MINE FIRE AT DOMINION NO. 1 COLLIERY, GLACE BAY, N.S.

By SHIRLEY DAVIDSON and NORMAN MCKENZIE.

Dominion No. 1, which is one of the oldest collieries in Cape Breton, was first mined by the General Mining Association in 1831.

It was abandoned for some years prior to 1893, when it passed under the control of the Dominion Coal Company, which sunk the present coal, air, and material shafts and equipped the mine with the most modern machinery, such as endless haulage systems, compressed air, self-dumping cages, electric haulage and electric lighting. The mechanical equipment on the surface consists of: Babcock & Wilcox boilers, of 1,696 rated H.P.; one coal hoist engine; one man hoist engine; two 26" x 60" haulage engines; three fans, 24 feet, 12 feet, and 8 feet, respectively, with capacities of 200,000, 75,000 and 25,000 cubic feet of air per minute; three air compressors in three units of 2,600 cubic feet each per minute; and one 100 K.W. electric 250 volt generating unit.

The bankhead consists of a steel structure equipped with up-to-date appliances for picking and screening the coal and delivering it to coal cars, and also to the colliery boilers and locomotives by means of 14" and 12" Robins Belt Conveyors.

Underground there are in use 62 horses, 46 mining machines and 340 pit tubs.

The colliery at the time of the fire was producing on an average 55,000 tons of coal per month, and employed about 800 men.

There are three shafts sunk and used severally for coal, air and material. The main or coal shaft generally used as an upcast—although the current may be reversed—is 154 feet deep from surface to rail, 10½ feet wide by 24 feet long, and consists of three compartments, two for coal and one for men. It is sunk below the pavement to a depth of 7 feet in order to bring the cage platform

with the mine track. The Fan shaft, 143 feet, 11 feet in eter, can be connected to either of the three fans, and is gen- used as a downcast. The material shaft, 135 feet deep, is 10 wide by 18 feet long, and is also used for the endless haulage , which are brought to the engine house located on the sur- directly alongside.

'hese shafts are sunk about 1,900 feet from the crop. The sur- n the vicinity is 89 feet above sea-level, while the pavement is et below sea-level. The surface from the shaft slopes gently e shore line of the Atlantic ocean, distant 1,800 feet, where it s away abruptly in low cliffs, exposing the seams of coal and emains of some old workings, supposed to be those of the h many years ago.

he seam worked, which is remarkably exempt from upthrows wnthrows, is known as the Phalen. It averages about 8′ 4″ ar bituminous coal.

he dip of the seam is in an easterly direction, the angle or in- ion of dip being about 1 in 15. The floor of the mine is a gritty shale, and the immediate roof is also a shale, which y falls at times, but is easily supported by timber. The plan rking is the ordinary "room and pillar"; the deeps, headways evels are driven 12 feet wide, and the rooms 22 feet wide.

he size of the pillars left at present is 25 x 70. The present of the workings have reached a distance from the shaft of feet in the North deep, 5,400 feet in the South deep, and 3,000 the Angle deep.

he overhead cover at the face of the North deep is 519 feet in ess of strata.

he mine made some 500 gallons of water per minute, but iso to take care of 800 gallons per minute from the Main and h slopes of Reserve, which quantity passed through a bore- n the barrier separating Dominion No. 1 from Reserve, and along No. 3 South level to the water lodgement on the back deep, from which it was pumped to the lodgement at the shaft n through a 7″ pipe. There are three water lodgements in t. One of 500,000 gallons capacity is located at the shaft n, one of 500,000 gallons capacity is about 2,000 feet from the on the North back deep, one of 900,000 gallons capacity is at e of the South deep as shown on the plan. The first two are ted as noted above, by a 7″ pipe laid up the North Main deep, wer pumping into the upper from two 14 x 8½ x 33, three hun- gallon Cameron pumps: the upper then discharges vertically shaft to the surface through one 300 gallon Cameron pump. dgement at the face of the South Deep contains a 1,000 gal- plex pump, which discharges vertically 430 feet through a

borehole into International Mine, from whence it flows by gravity to the sea. Another borehole driven from the surface, 519 feet in depth, contains the steam and the exhaust pipes one within the other. Steam is supplied by the boilers at International Mine, located on the surface almost directly overhead.

The underground workings of Dominion No. 1 cover an area of 560 acres, and had produced from this area while under the management of the Dominion Coal Company, approximately 3,400,000 tons up to the time of the fire.

Inflammable gas is met with in very small quantities in the workings, but a sufficient amount of ventilation is maintained by a powerful 24 feet Dixon fan, which circulates 114,000 cubic feet of air per minute with one inch water gauge.

A water service is maintained for boiler supply and other purposes on the surface through a 6″ pipe leading from a small stream distant about a mile from the Colliery. An efficient supply is kept up by a 250 gallon 14 x 8 x 12 Knowles pump. The stream is dammed, and forms a reservoir capacity of 7,000,000 gallons on the edge of which is located the boiler, pump and pump-house.

About 3.30 in the morning of Thursday, March the 19th, 1903, a workman returning from work discovered fire in a cross-cut between the Back and Main North Deeps near No. 3 Landing, about 1,200 feet from the shaft bottom and about 147 feet below sea level. The opinion is that it was started on the back deep side of the stopping by a workman carelessly throwing away the lighted wick from his lamp, or, contrary to all rules and regulations, kindling a fire in order to warm tea. This back deep is used as a travelling road, and the stopping in question was the same as all others built in the cross-cuts in the pillar between the Back and Main North Deep. It was composed, as most of them are, of hemlock boards lined with brattice cloth: the average width of this particular cross-cut was 12 feet. Some loose boards were lying alongside, and it is probable that some rubbish had also collected, as is generally the case in the waste places of mines. On account of the location, the fire was an exceedingly difficult and dangerous one to deal with. Alongside of it to the North was an old and abandoned section, where some time previously a bad crush had made it necessary to protect the pillars along the travelling road with a considerable number of props lagged behind. The workman who made the discovery, instead of making any attempt to stamp out the fire, as might have been done in this early stage, fled to the shaft bottom. This he reached after a difficult passage through the smoke, which quickly collected and poured up both North Deeps with the air current to the shaft.

gave the alarm to the Underground Manager, who with an
n immediately travelled directly towards the fire, through
ke, on the Back Deep. Orders were given to the bottomers
w down with buckets. When within seven hundred feet the
the fire was dictincly seen, extending across the Deep, and
e cross-cut was reached, the place was a mass of flames,
top of the coal was scaling.
hovel—the only appliance at hand—was of no practical
was impossible to get about the fire, on account of the
moke, and the Underground Manager, seeing that the fire
ond his control, with the limited assistance of one or two
hand, made for the shaft bottom for proper appliances and
lp. The men at the bottom refused to give this, so he started
one, but this time by way of the Angle Deep and No. 6
Level, when he met some miners, who followed him to the

ers had been given to send down hose to connect with the
ch discharge from the lodgement nearby. The first lot was
ed on the Angle Deep so that this connection was not made
arrival of the second lot, by way of the South Deep.
sted by the air current the smoke quickly gathered in
and barred all entrance to the pit by way of the shaft.
Kenzie, the Manager, who was immediately notified, was
ed to enter the Pit by the travelling slope, which is driven
e crop about 1,300 feet north of the shaft. He first reduced
d of the fan. On the way down he gave orders to remove
es, but all were suffocated before this could be done. As
g by either of the North Deeps was impossible, he pro-
ver the air crossing at the fan shaft bottom and through
shaft to the South Deep, and down the South Deep to the

ber and brattice were then put up across the main deep as
possible means of excluding air from the fire.
seven-inch discharge line from the lodgement nearby was
and after considerable delay in receiving the hose, two
ere connected to it. One was carried directly to the fire
t, while the other worked through the first cross-cut above
in the Main North Deep.
this time the Back Deep had already fallen, so that it was
ble to follow the fire through the cross-cut, where it had
and the work of extinguishing was therefore practically
to the Main Deep, which was not so badly fallen, and
e more accessible. The opinion is that had the fire been
to this deep alone it could have been extinguished with
er and hose available, but it was quickly travelling up the

Back Deep and darting through the cross-cuts to
above the point where the men were stationed.

The morning of the fire it was difficult to per
work, as the conditions were very similar to tho
not long before, when a fire broke out in that
an explosion occurred, causing the death of eleve
the Underground Manager, who had formed a par
In both cases the fire was near old and abandone
with damp. This made the men nervous and
time, but after the first day there was no difficulty
the men required.

The Managers from the different collieries ca
with them their subordinate officials and any men
perience with fire in a mine. These were organize
of eight hours each, one of the Managers being in
shift, with a mine official leading each gang. Eac
posed of five gangs who fought the fire from diffe

The Fire Brigades from Glace Bay and Sydne
of these gangs, and brought with them all the av
sides those fighting the fire, a gang on each shift
mining machines, mine tools, etc., from the pit.
busy sending down material, such as brattice clo
while a third took charge of the ventilation, and
travel all the places clear of fire and smoke and t
accumulated in any part of the mines.

Two more lines of hose were now laid from t
down the South Deep and across to the Middle D
from the top cross-cut, into the Main Deep, whil
carried down to the next cross-cut in the middle
supply of water was kept on these by means of
pumps, which were temporarily set up alongside
the dam and driven by steam from a locomotive
track. Two lines of wrought iron pipe 5" x 4" r
laid from this point along the surface to the shaf
was connected and dropped to the bottom. It wa
to ascertain the distance the fire had travelled
bottom on the Deep Back, as the only two cross-cu
those between the Middle and North Deeps, and t
made use of to fight the fire on the Main Deep.
other passages to the Back Deep. This being the
was made to reach a point 600′ above the fire cr
Back Deep by following down the old horse road
Deep. After several attempts this point was
smoke was so thick and the heat so intense, tha
short inspection could be made, it revealed the

Deep had fallen in up to this point, although no fire was in
A line of hose which had to be carried along to this point
ft open. The drain which carries some of the water from
e through the rise workings of Dominion No. 1 amounting to
500 to 1,000 gallons a minute was also diverted to this point
lowed to flow into the Back Deep.

, contrary to all expectations, the fire was not seen at this
another attempt was made to reach it in this crushed dis-
hrough room 30, which intersects the Back Deep a short dis-
above where the fire started. The object of this was to find
the fire had worked its way through the stone stoppings
separate the back deep from the crushed and abandoned
nd also if possible to break through these stoppings and
the same method of fighting as on the Main Deep, namely
and behind. This method promised reasonable hope of suc-

the night of March the 23rd, 1903, after a very difficult and
ous passage along room 30, a point was reached 750 feet
he Angle Deep and 200 feet from the Back Deep stopping,
it was discovered that the fire was making way into the old
The necessary pipe had been laid down the Angle Deep and
d been carried along to this point and was ready for use,
attempt to extinguish the fire by this means in this old and
ned section with its scores of openings, dangerous roof and
illing was absolutely useless and a waste of time.

e work of fighting the fire from behind on the Main Deep
tching it at the first cross-cut from the Centre Deep was
ed under the most disheartening circumstances, for the
ons were most unfavorable, as the section was the worst in
ne. The behaviour of the men was splendid, although they
re damp existed, and there was constant danger of an explo-
nd in spite of smoke, heat, and falls of roof which drove
ack time and again, they stuck to their posts till all hope
ng the mine was abandoned.

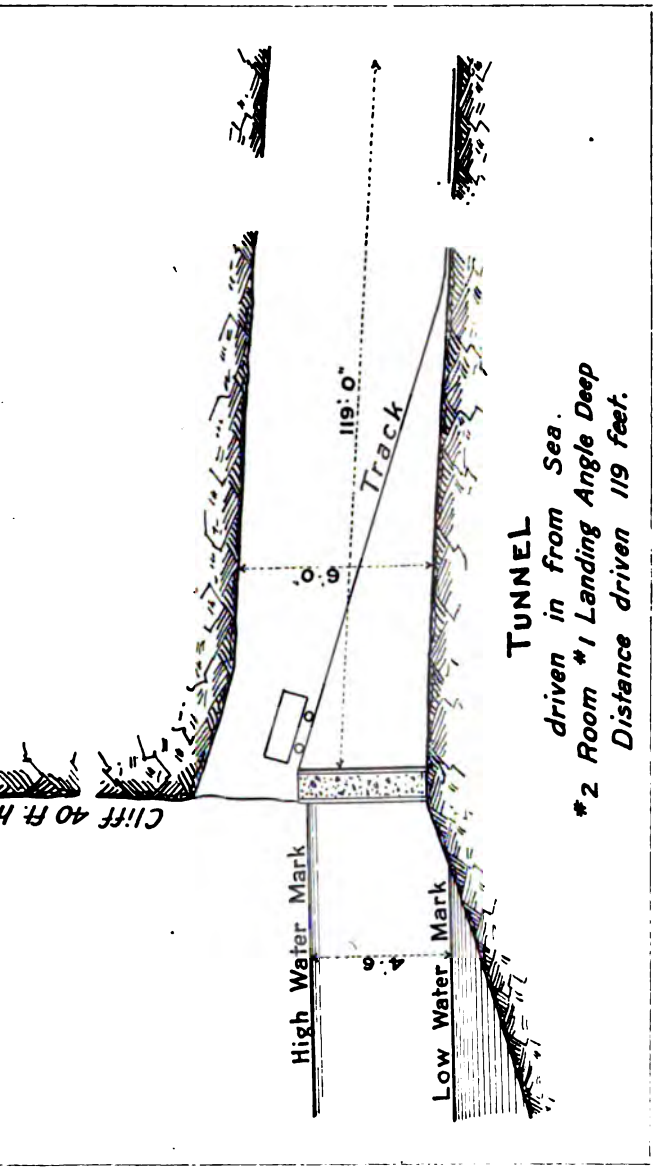
e fire was now travelling so rapidly, that fears were enter-
for the safety of the shaft, the loss of which meant the loss
pit. A careful survey was made of No. 4 North Landing
rtain if it was possible to construct dams of sufficient
h to retain water in this section, but the pillars were so
crushed and the roof so badly fallen that this was con-
impossible, especially as time was of so much consequence.
e question of submerging the whole of the north side was
ned for the same reasons. In the meantime two dams had
uilt across the roads connecting the North and South
in order to protect and keep in operation the big 1,000 gallon

pump, which took care of the water from the low
pit. These withheld a considerable amount of wa
side and kept the pump for the time being from
by the water which was now entering the pit
quantities through the hose and drainage from Res
ascertain how far the fire had travelled up the Ba
this time, Mr. McKenzie and several others after s
ful attempts, in which the lamps were extingui
finally succeeded in reaching through five feet of
600 feet above the fire cross-cut, where it was dis
fire had passed this point, and was quickly appro

After this discovery on Saturday, March 28th,
after the fire started, complete submersion was d
the mining machines, with the exception of two,
miners' tools, all horses, including the dead, were
the pit, together with parts of the electric locom
was then sealed as closely as possible to prevent
gen entering to the fire, but it had been worked
under a cover of only 100 to 200 feet, and the falls
ing the pillars had extended to the surface, and th
possible to exclude the air completely, even after t
precaution. This was later proven by analysis of
after the mine was sealed. As can be seen from
below, the carbon dioxide was very much highe
than on May 10th, which shows that the fire could
extinguished by the method of excluding the oxyg
conditions.

	CO_2	O.	N.
April 30th..	4.0	2.4	93.2
May 2nd	4.8	5.4	39.8
May 4th	5.2	3.6	90.8
May 5th	5.4	4.0	90.4
May 7th	4.4	6.8	88.8
May 9th	2.4	10.6	87.0
May 10th..	3.6	8.8	87.6

No time was lost in turning on water from
sources of supply. Through an old room in the
drain was driven through to the crop to catch the
brook flowing by this room. One 1,000 gallon N
two portable boilers were set up on the shore of
tant 800′ from the travelling slope. An 8″ pipe w
these boilers and the mouth of the slope. This
with that from the small brook, united with the d


Cliff 40 ft. h
High Water Mark
Low Water Mark
4'.6"
6'.0"
119'.0"
Track
TUNNEL
driven in from Sea.
*2 Room *1 Landing Angle Deep
Distance driven 119 feet.

serve, and flowed down the travelling road into t
above the fire cross-cut. This amounted to 1
minute, or in the fifty days from April 1st to Ma
gallons. It was estimated that 516,000,000 gallon
to bring the water to a level that would cover th
now extended nearly to the shaft bottom.

To have filled the mine from this supply al
taken many months. To hasten the submersion,
call into requisition the waters of the Atlantic. A
6′ high 6′ wide was driven in from the shore to t
which was Number 2 room, Number 1 landing on
This was driven in four days, or an average of
machine cut, for which an air line had been laid
from the compressor house. The coal was loaded i
the track laid for the purpose, and hauled out to t
While the work was in progress a temporary dam
across the opening, in order to seal off the pit a
it would otherwise have filled the tunnel, and de
This was composed of two walls of three inch pl
an eight inch space, which was filled with concret
four feet by four feet located above high tide, aff
entrance and exit to and from the tunnel. Be
completion, another door four feet by four fe
used as a means of regulating the flow of water i
sea was first let in on April 7th and finally closed
period of 46 days—but the flow of water was not
actual time of flow in this period amounted to fif
which it is estimated that 420,000,000 gallons ente
rate of 28,000,000 gallons every 24 hours. 96,000,00
by the other means mentioned, which totals 51
This brought the water level with the bottom of

After the pit was submerged the opening was
manent dam, which consisted of 92 pieces of spru
inches by 10 inches at one end, and eight inches
the other end, each piece being faced on two side
pine boards. Its thickness was about seven feet
lower portions of this dam a 17″ diameter pipe was
at the lower end, which was forced into the pipe
of the sea when the flooding was completed.

Readings of the rise of water in the pit were
of a float and wire dropped down the borehole to
South Deep. The waters of the sea were shut of
time on the assumption that large quantities were
upper workings by falls and other obstructions,

iings showed that water raised the level at the bore hole for ›ral days after the sea tunnel was closed.

Another source of anxiety and cause of delay in flooding was question of the strength of Reserve Barrier. Below No. 5 South el of Dominion this was sufficiently thick to withstand the sure brought to bear on it, but above that point or from the om of Reserve Main Deep the surveys showed varying thick-es. The water from the Main and French slopes of Reserve ed through a borehole driven through the barrier at a point in face of No. 3 South Landing of Dominion, and here the thick- was 53 feet. The face of the Reserve Main slope is 198 feet w sea level, which when the water was on a level with the om of the shaft was under a level of 130 feet, or 57.2 pounds per re inch, which equals 4.1 tons per square foot. To guard nst any possibility of accident through the failure of the bar- and in order to protect the workings of Reserve other than e of the main slope, two dams consisting of 10″ x 10″ spruce hemlock laid in two walls with four feet of concrete between e built across the narrow places of No. 10 Landing, which was only connection between the main slope and the rest of Re-e. The barrier however proved effective. The water worked ugh the strata and came in in considerable quantities through roof between No. 9 and No. 11 landings, but outside of heavy lensation on the face of the barrier no other noticeable features eloped.

The filling continued as above described until the readings n at the borehole indicated that the water had reached the om of the shaft, but a float lowered into the shaft showed that water had not reached this point. A close examination of the hole was then made, and it was found that water bailed out by icket lowered the water about 25 feet, showing that the read- taken were not a true indication of the rise of the water in the This method was therefore of no value, and, without any er gauge, the regulation of the flow of water became a matter of gment.

On April 30th, 21 days after the mine had been first sealed, m in place of smoke began to issue from the test holes in the ft, proving that the water instead of being on a level with the om had apparently only reached the fire territory. An addi-al 250,000,000 gallons was therefore necessary to cover this.

Great care was taken to keep the water from actually cover- the shaft bottom, as a rise above that point would entail much a labor and loss of time in pumping out, for then the pump- would have to be started by way of the travelling road by placing some pumps in the shaft. To provide for this

emergency an air line was laid from the compres
mouth of the slope but there was no necessity to

On May 11th the pit was opened, and the fan s
made its appearance. The pit was again closed,
let in, and again opened on the 23rd May,
was found. On May 23rd a small hatch 7″ x
in the coal shaft, and at the same time a
opened in the tunnel at the shore. The air th
from the trap door at the shore across the fire di
coal shaft.

Parties were organized for searching, undergr
superintending operations on the surface. The u
entered the pit by the travelling slope. Conside
met with, but great care was taken, and no acci
The temperature reached 114°.

Another party which entered the pit by the tu
was once driven back by damp, but next day succ
ing with the party on the travelling slope.

On May 24th 7.30 p.m., the fan was started ex
main shaft was uncovered. From this time the
up and arranging for pumping out the pit wa
ried out. The water had risen to the shaft botto
although partly covered, was started on May 30th,

One of the greatest mine pumping proposition
fore the Dominion Coal Co. Time was of great co
count of the demand for coal. The total quanti
quired to be pumped amounted to approximately 5
besides what the mine made through feeders and
to 500 gallons per minute. When it was decided
telegraph enquiries had been sent to all pump m
and sizes of pumps on hand for immediate
was a case of taking almost anything that
mediately shipped, and the material and machin
this purpose consisted of the following pumps:—12
14x 18½ x 10—500 gallons; 4 Smith Vaile Duplex,
gallons; 4 Jeansville 12 x 8 x 18—600 gallons; an
ton, 14 x 12 x 10 Duplex—1,000 gallons; making a
22 pumps of a total capacity of 12,800 gallons per m
amounted to 27,000′ of 8″, 24,000′ of 6″, 900′ of 12″,
26,000′ ranging from 5 to 2½ inches.

On the two South Deeps 8 pumps were worked,
to the surface through four 8 inch pipes. They w
sets of four on each deep, two pumps connecting t
charge.

These sets were staggered and moved down

e suction reached a length of 350 feet. The North Deeps o the fire were so badly fallen that pumping could not be ed in them. Four pumps were therefore carried down the Deep and discharged up the shaft to the surface till No. 1 g was reached when discharge lines were laid along this to nel opening to the sea, thus cutting off 80 feet of head. mps on this deep were carried along on a suction of about t until No. 4 Level was reached, when they were moved the Centre and North Deeps, discharging to the sea through inch discharge lines.

en the water receded below the lodgement on the North his lodgement was used as a second lift. Five pumps were at this point, and water was delivered to them by the four g down the Middle and North Deeps. The eight pumps g on the South Deeps were then pumping to the pit bottom ent from which four large pumps pumped to the surface h the material shaft. The pumping was of necessity at times ow on account of the numerous falls which had taken place shifting of pumps and by the resumption of mining before was clear of water.

May 30, 1904, just one year after the beginning of pumping ons, the mine was completely pumped out. Besides the ,000 gallons which filled the mine, the mine was making 500 gallons per minute during this period, which amounted to imately 276,000,000 gallons. The total number of gallons l was therefore 792,000,000.

t taking into account the work done by the pumps at the lift, the performance of the pumps was as follows:—

Knowles	47,846	hours.
Smith Vale	9,640	"
Cameron	111	"

e results show that the Knowles and Smith Vaile and Cam- umps worked constantly during this period at an average of their capacity or at the rate of 250 gallons per minute, or gallons per hour of the Knowles and Smith Vale, and 12,000 per hour for the Cameron.

e Air Compressors which kept these pumps in operation orked to their full capacity. To relieve them the pumps around the lodgement at the shaft bottom were driven by

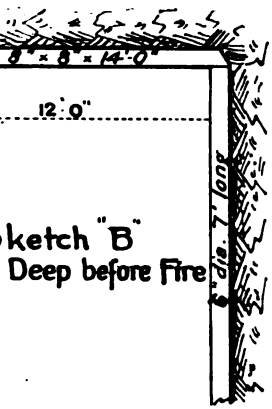
e action of the gases from the fire on the pipes, ropes and ork around and in the coal shaft was very destructive. All e and pipe that had been exposed to it were so badly eaten mplete renewals were necessary.

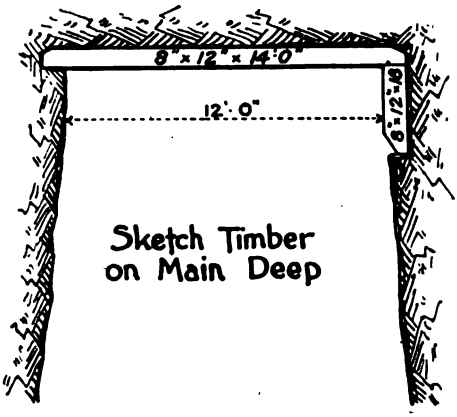
In the fire section of the mine both deeps on th
fallen completely to a height in some places of 12
shown by the crossed shading in plan. In very fe
possible to crawl over these falls. This necessitat
and expense in cleaning, tunneling and timbering
travelling road and haulage way in a fit condition
Even if it had been possible to do without the use
the shale and roof coal were found to give off a ce
heat, on the haulage road particularly. For this re
sidered better to clear it out than to run the risk
ing again on this deep. There was no apparent r
temperature of this material should have been so m
at any other place to which there was access, un
which was very fine, combined with oil dropped fro
axles, made the condition more favorable for spont
tion, and with the enormous weight of the roof t
pressing upon it, excluding the air current.

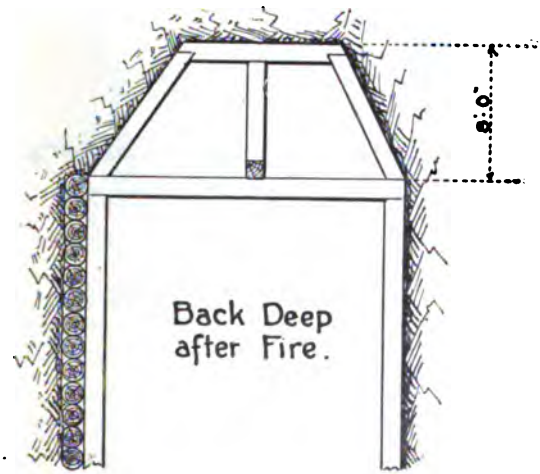
The stone removed from the falls amounted in
to 25,000 tons, and was removed from the pit. T
clude about an equal quantity which was removed
reaching the working face, as this was stowed in t

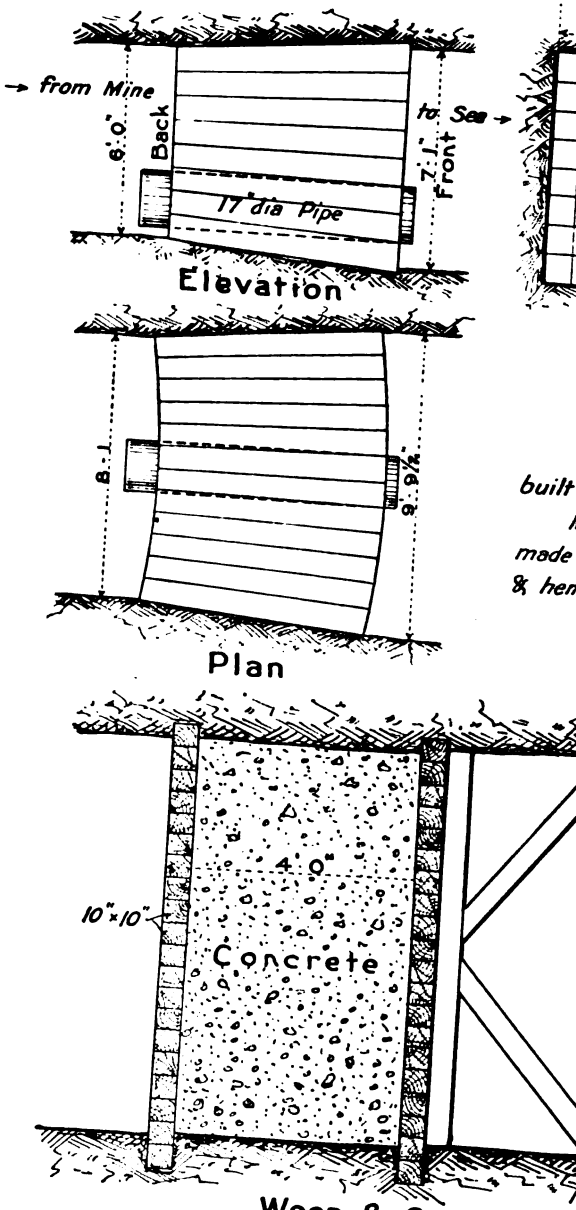
The places where these falls had taken place
timbered. About 3,000 booms were put in besides
for lofting. In some places where the roof was ve
were used in the centre of the boom, but generally
placed in the rib or pillar and required no prop.
course used and lagged behind where the pillar wa

No harm was done to the shaft, but around
tom, as shown on the plan by parallel shading, the
heat on the roof made it necessary to bring it dow
two feet, which greatly improved the condition of
the place.


8" × 8" × 14'-0"
12'-0"
8" dia. 7' long
ketch "B"
Deep before Fire


8" × 12" × 14'-0"
12'-0"
8" × 12" × 8'-0"
Sketch Timber
on Main Deep

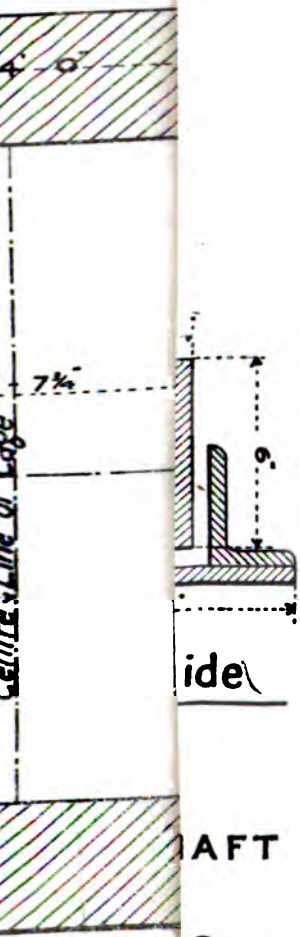

8'-0"
Back Deep
after Fire.



WOOD & CONCRETE

On Level connecting M

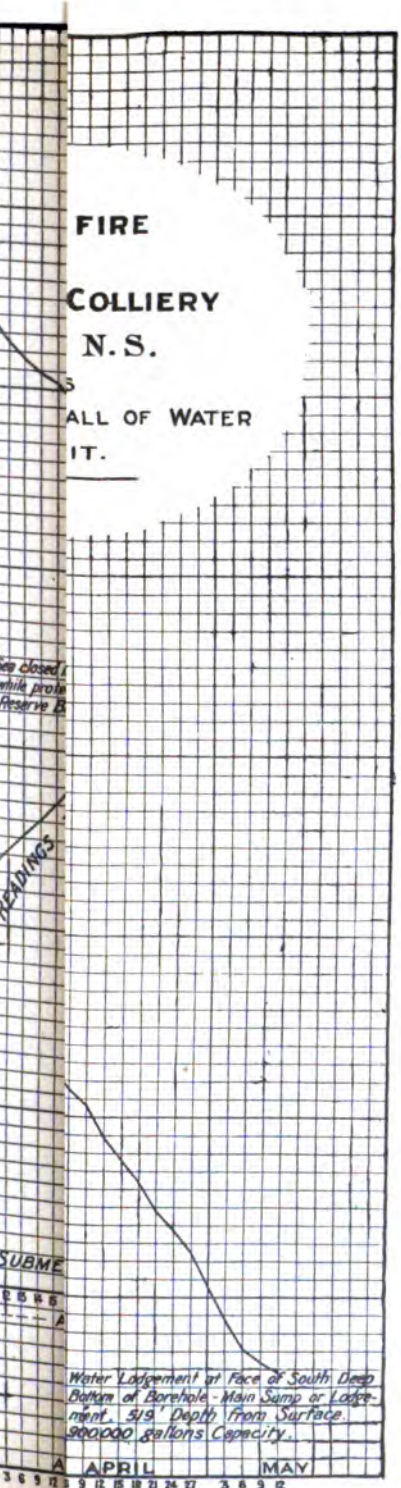
French Slopes of Re

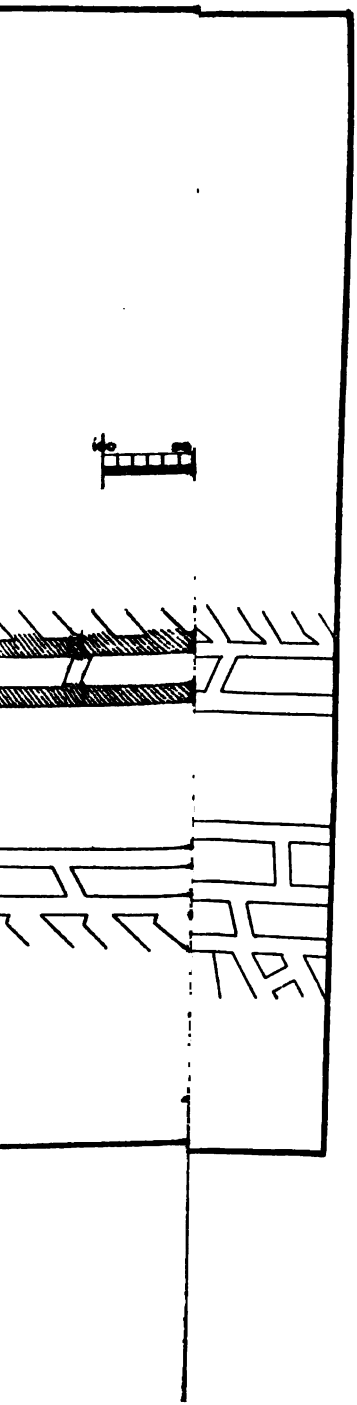


ide

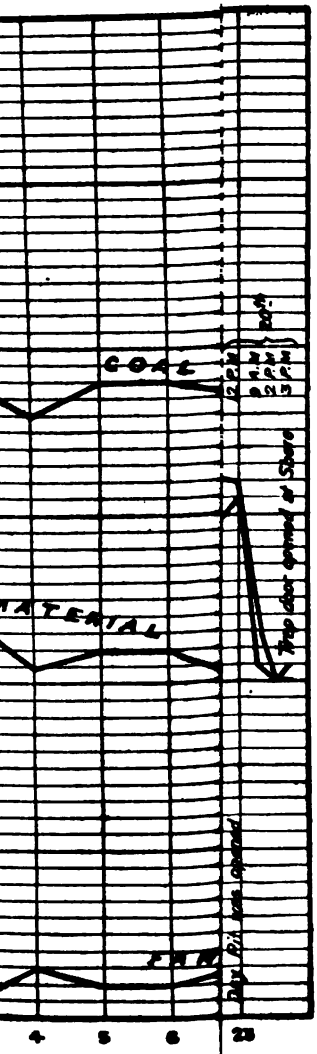
AFT

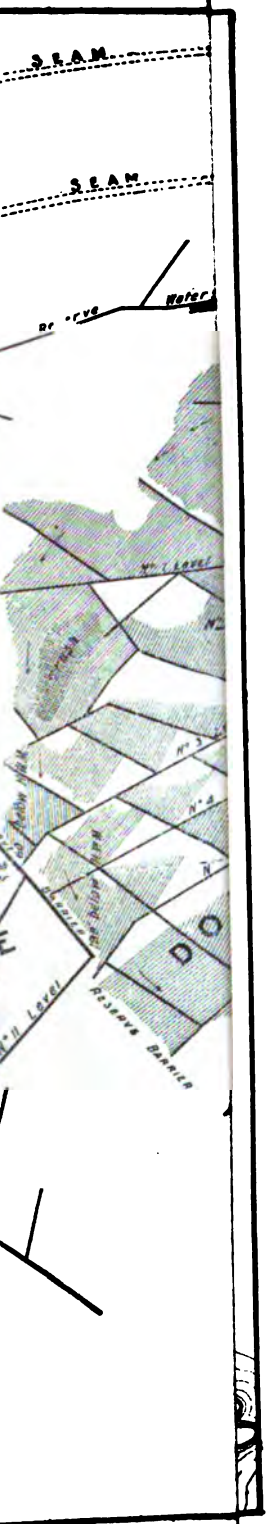
COLLIERY.


FIRE
COLLIERY
N.S.
ALL OF WATER
IT.
Water Lodgement at Face of South Deep
Bottom of Borehole - Main Sump or Lodgement. 519' Depth from Surface.
900,000 gallons Capacity.
APRIL
MAY



MINE FIRE
RECORD




SEAM
SEAM
Water
Reserve Barrier

DISCUSSION.

Mr. J. E. Hardman said that if the authors of the paper were ent it would be interesting to bring up several points in discus- but in their absence, he felt a delicacy in doing so. He might however, that he could not see why it had taken the colliery agers nine days to decide to submerge the mine. Mr. Hardman.

Mr. E. G. Stairs replied that he believed one reason was that was a great deal of slack coal in the neighborhood of the and the map showed that in the immediate neighborhood there crushed pillars. Probably the fire remained in this place for ng time, and did not look as bad as it really was, and thus uraged the management in their hope that the fire was not us. Mr. Stairs.

Prof. Porter said that there was nothing in the paper or cor- ondence which touched directly upon the point brought up by Hardman, but on one of the maps there was a small area ked: "The fire was confined to this place for several days." Prof. Porter.

GENERAL SECTION.

President—D. MacPherson.
Vice-President—C. H. Keefer.

A meeting was held Thursday, February 23rd,
MacPherson in the chair. The following paper
author:—

PAPER No. 224.

PORT COLBORNE HARBOUR W

Description of Design, Methods and

By J. M. Hogan, S. Can. Soc. C.

Port Colborne, situated at the southern or La
Welland Canal, marks the limit of clear lake na
this point to Montreal the draft of vessels is con
the legal allowable draft of canals, which for the
13' 6".

The Canadian Government has, since 1900, be
tensive harbour improvements with a view to n
borne a transhipping point of large dimension
possible, to Buffalo. Should the Port Colborne
as intended, the navigation of the canal system
augmented where at present, despite free tolls,
especially considering the facilities offered and th
of the canals.

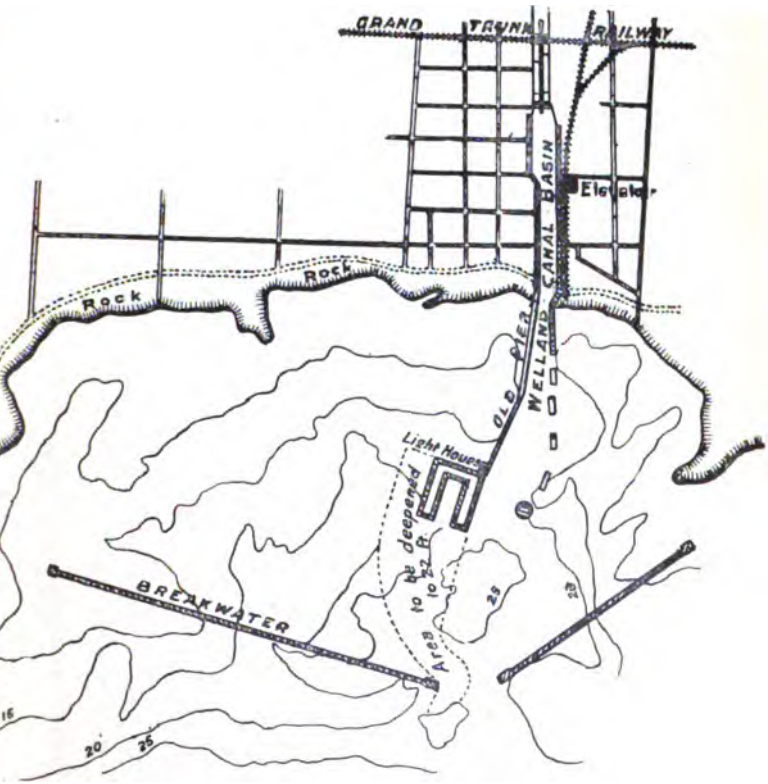
Much of the grain which at present goes to B
lake carriers and thence to New York by rail or
be diverted to the St. Lawrence route were pro
vided at Port Colborne for transhipment, and it
just such facilities that the works were undertak

Fear of such a diversion of trade doubtless
of the proposed large expenditure of $100,000,00
New York in deepening the Erie Canal; but eve
state the Erie Canal route will be inferior, both
(10' as compared to 14') and distance, for the S
(Port Colborne to Montreal) is shorter by over
Buffalo to New York waterway.

The works comprise new docks, excavation
two large breakwaters to east and west of the p

, of which one, 5,000′ long, is finished, while the 2,400 long, is half completed, are under the supervision of ment of Public Works. The rest of the works are controlled e Department of Railways and Canals. This paper will s only the latter.

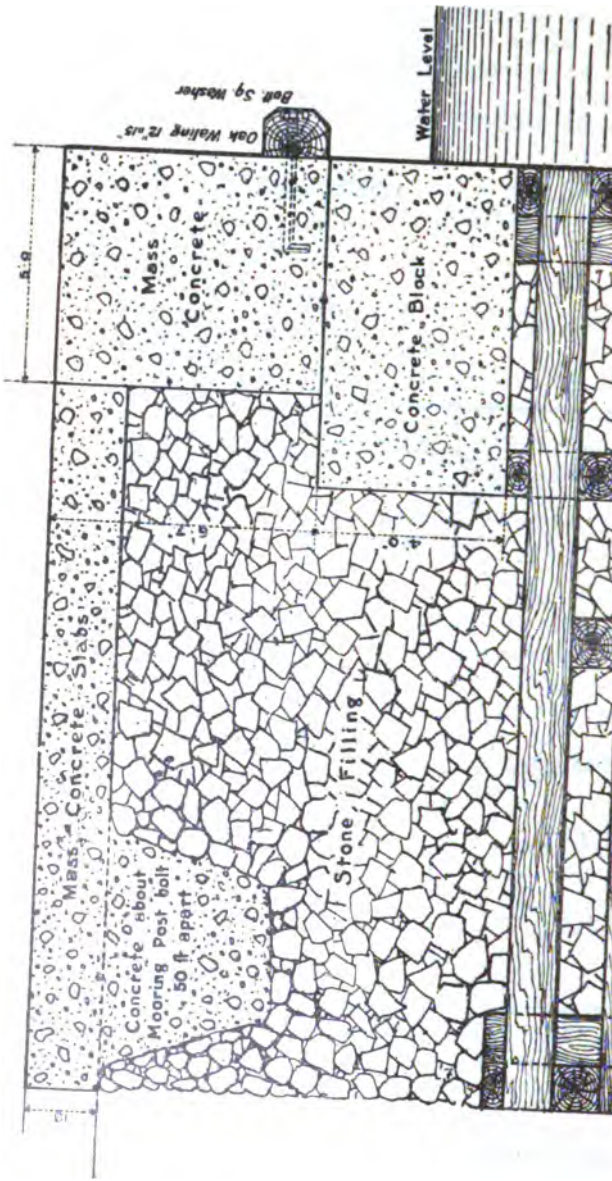
e work may be divided into excavation of channels and

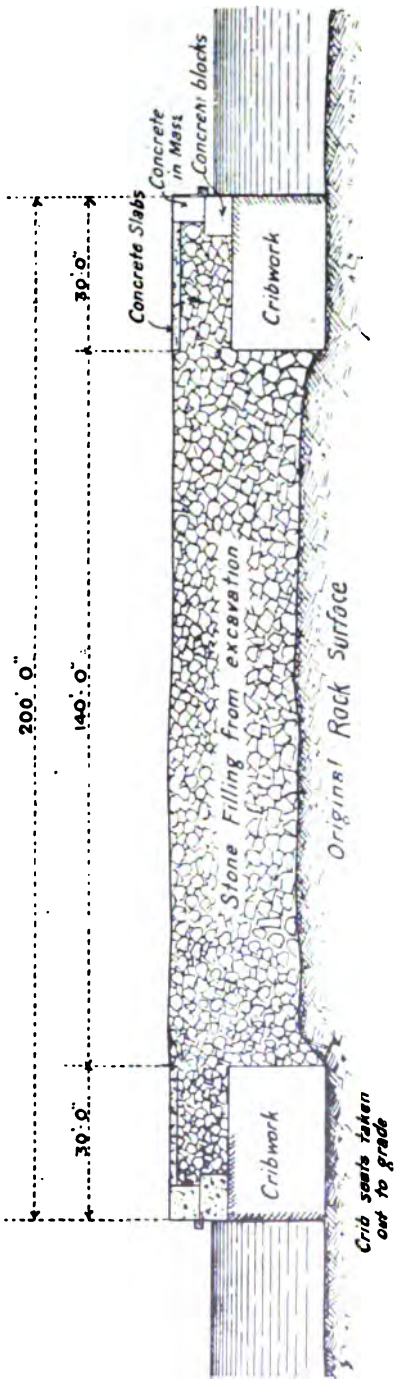


T COLBORNE HARBOUR IMPROVEMENTS

Fig. 1.

roviding of new docks. Beginning at the breakwater, a depth is to be made to the north end of the canal basin and in the ty of the two new docks built at the end of the old pier. All s excavation up to the entrance of the canal basin is in solid


Water Level
Bolt Sq. Washer
Oak Waling 12"x15"
Mass Concrete
Concrete Block
Mass Concrete Slabs
Concrete about Mooring Post bolt 50 ft apart
Stone Filling



SECTION THROUGH PIER.

Fig. 3.

rock, over 300,000 cubic yards in all, averaging a
over its area. The limit of deepening to allow o
new outside docks is shown on the plan (Fig. 1).

These new docks, which are 700′ x 200′, toget
docking provided along the sides of the canal bas
in all about 1½ miles of concrete docks, allowin
vessls up to 22′ draft. On one of the outside doc
an elevator for transhipment of grain.

Dock Design.

Design of inside and outside harbour docks is
width of crib. Figures 2 and 3 show the
essentially submerged crib work filled with stone
by concrete blocks carrying a mass concrete
covered for width of crib by an 18″ slab of concret

These cribs are built to within 2′ of an assun
(14′ above mitre sill of lock) so that no timber
The use of concrete blocks does away with the
of placing green concrete under water, and ensur
in a position where permanency is required. Crib
cases dug out to grade with dredges, but the in
docks were left as found.

Cribwork.

Plan "C" shews details of cribs. The outer h
30′ wide as against 20′ for inner harbour, the ex
called for by the exposed position. The constructi
vary beyond the extra solid bulkhead in the 30′

The timber used, about 35,000,000 ft. B.M. in
12″ square hemlock, proud edged with the small
allowed in ties or longitudinals. A small quantit
used for bottom grillage and block seat.

Ties and longitudinals are dovetailed, as per s
placed at intervals of 10′, except in lower course,
tie is put in every 5′. Side joints are simply but
cut exactly square with ¼″ allowable opening.
alternately. The longitudinals form two solid bul
length of the crib, which is a feature of great stre
for short 10′ fillers between ties on every second

Binders are placed every 20′ with the object
courses together vertically.

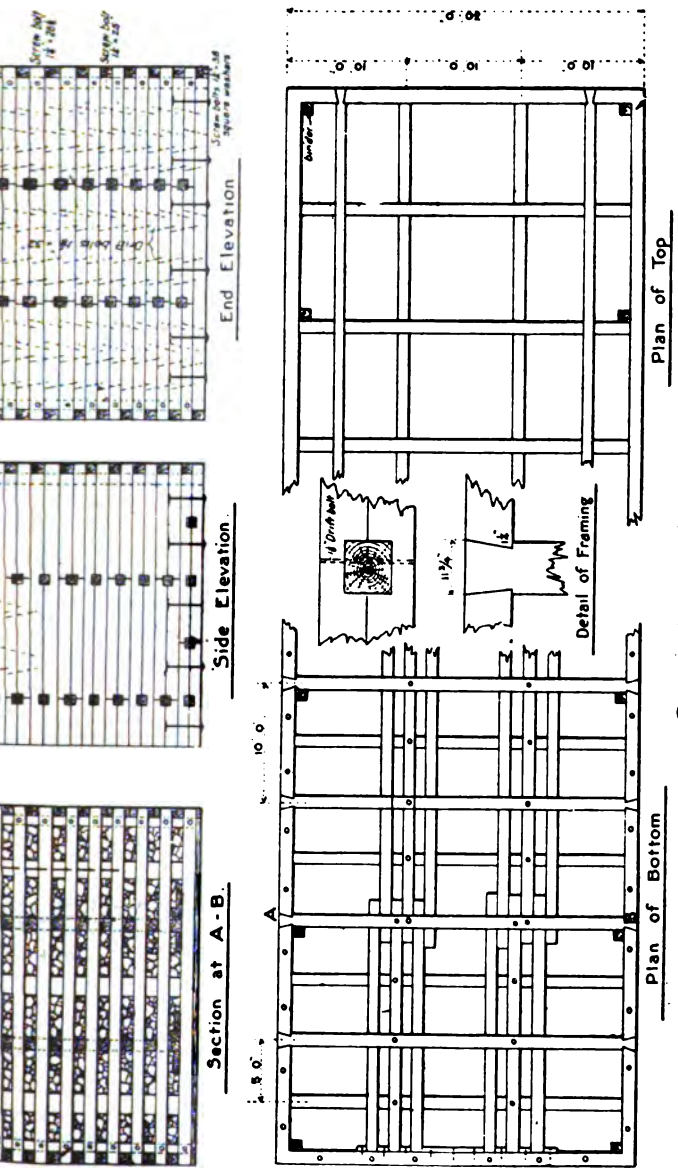
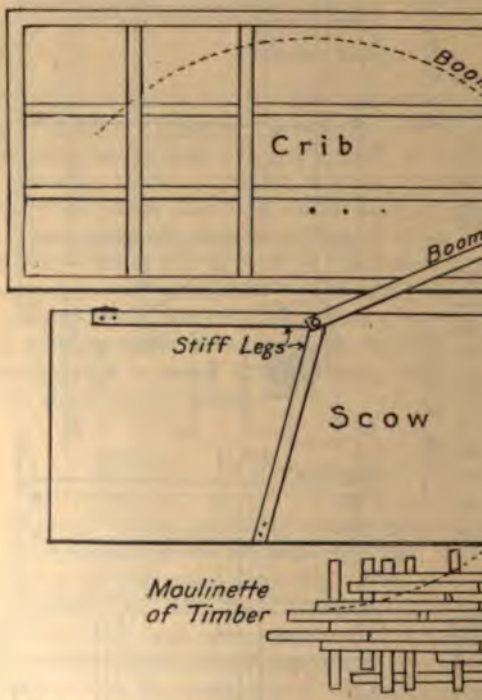

End Elevation
Side Elevation
Section at A-B.
Plan of Top
Plan of Bottom
Detail of Framing
DETAILS - 30 x 100' CRIB.

Fig. 4.

BOLTING, ETC.

Binders are fastened to face timbers and
screw bolts with square plate washers.

The three lower courses of crib are made
withstand stresses caused by filling, weight o
uneven bottom, and rough usage in handling



METHOD OF BUILDING CRIBS

Fig. 5.

ened with 1¼" x 36" screw bolts and washers
whole three courses and spaced 5' apart. Th
bolted as shewn with 1⅛" x 32" drift bolts ha
These bolts pass through two entire courses an

The short blocks shown in section, coming
rear of concrete block, aid in preventing any
and consequent settling of wall.

hese cribs are built on ways up to 7 or 8 courses, and then hed and finished in the water. Owing to depth of water in asin being insufficient to float a finished 20 course crib, it was sary to tow cribs into the open lake, and finish them near sites.

ribs were built by derricks afloat on scows. A feature was iacing of the derrick at the edge of the scow, and so arrang- ie stiff legs that the derrick boom could have greatest possible s of action. Only one move was required by the scow to lay a course of timber. Hoisting engines having boom fall and ing drums were used, so that the engineman controlled the movement of a stick of timber. The timber was unloaded vessels directly into the water in piles or moulinettes; this the most convenient method of storing the enor- quantities of timber used. As required, the moulinettes were alongside the crib scows and built directly into the cribs. imber was thus placed in the crib with only one handling, as iip was bound by contract to unload its own cargo.

he crib scow also had an air compressor plant to supply natic augers used for boring, as all drift bolts were driven noles bored $\frac{1}{8}$ to $\frac{1}{16}$ too small.

gang of 20 men in all launched two crib bottoms of 7 courses inders regularly each week, while a completed crib repre- l about 8 days' work.

ribs were sunk by placing on them several concrete blocks on orary platforms at ends and middle. When properly aligned evel the filling was dumped in as rapidly as possible, and s later placed in their proper position. Owing to weather tions the filling of each crib had to be completed at once, or 2,000 cubic yards of stone filling provided. All this filling iredged up from the excavation referred to.

Concrete Blocks.

hese blocks, 4′ x 4½′ x 7′, were moulded in timber forms made dressed pine, tongued and grooved. A piece nailed to the side ould gave the reguired joggle to the block. The moulds were across by two ½″ round iron rods with nuts, threaded both The lower rod passed through the partition forming end l of block.

ides were held in position by the shoulder formed by lapping ′ x 4″ upright. To remove moulds, nuts are slacked and hts taken down, when the sides will remove in one piece and be utilized again. These moulds were filled with concrete in s and allowed to set for 48 hours before removal of moulds.

After five days these blocks were sufficiently set t
derrick.

In top of the block is a basin-like depressi
side a slot or joggle is moulded. When blocks a
side, the mass concrete of wall filling up joggle
strong joint between each block and between top
above, and prevents any lateral displacement of
the wall which might be caused by impact of the
vessels.

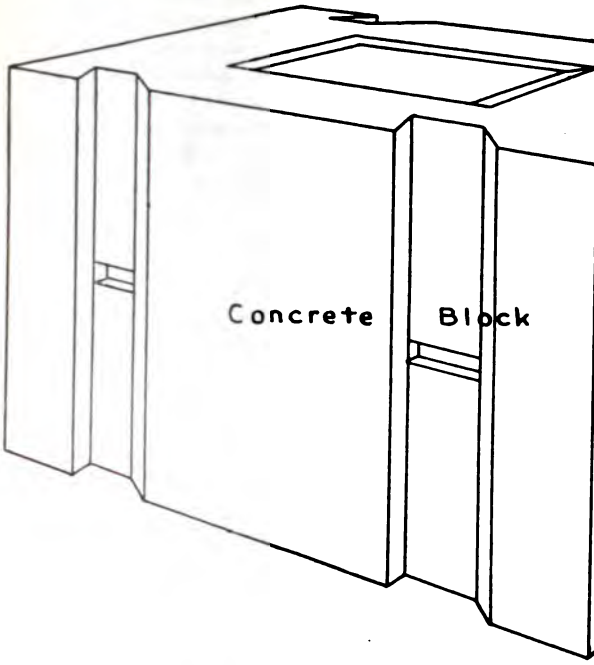
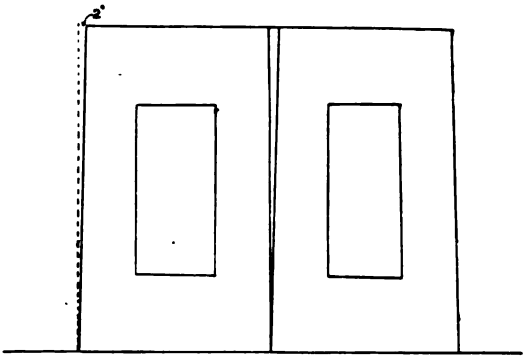


Fig. 6.

The joggle also allows of the simple method
blocks shewn in Figure 4.

Much difficulty was experienced in setting th
and close jointed, especially the latter. This wa
even character of the bed left by the dumping in o
the difficulty of levelling same in 2′ and 3′ of wat
obtaining close joints the blocks are now made wi
from face to rear of block which allows of the
brought closer to the neighbouring block.

ulds for the concrete wall are of similar material to block and similarly fastened, except the lower rod, which rests block and supports outside upright which overhangs the face . This rod remains in the wall. The rear upright is into the joggle. Moulds were erected in sections of 60 to 75 day's work. The next day's work began at finishing point of s day, which allowed sufficient expansion. Canvas nailed le face of mould and allowed to drape over the block, was vely used to prevent washing out of concrete by seas before ghly set at the level of block.



SHOWING BATTER OF BLOCKS.

Fig. 7.

CONCRETE.

crete was 1. 2. 4. mixture. Owing to the large area covered by rks it was impossible to set up a permanent plant anywhere. nvenient approaches to most of the work being by water, n of utilizing a floating plant was adopted with good results. large deck scow was equipped with a derrick, mixer, and , and storage provided for cement and sand. The lay-out arranged that the derrick, having 68′ boom, controlled all erations. Materials for the day's work were loaded each g. and the scow towed to the site. The stone for crushing tained directly from the back filling of the cribs and hoisted crusher platform in tubs, where two men fed it continually crusher. This stone, being dredged from the bottom of the as clean and excellent for concrete. The stone thus crushed ut below into another skip or tub. When 3″ or 4″ have ac- ted the spout door is closed and a wheelbarrow of sand from

the pile close at hand is dumped in and sp
three bags of cement. This alternate pro
the box is filled, when it is hoisted up and
bin of the mixer, and thus runs in a contin
mixer itself and into moulds below. Beside
system is compact. Where stone was not a
it was brought alongside in scows and us

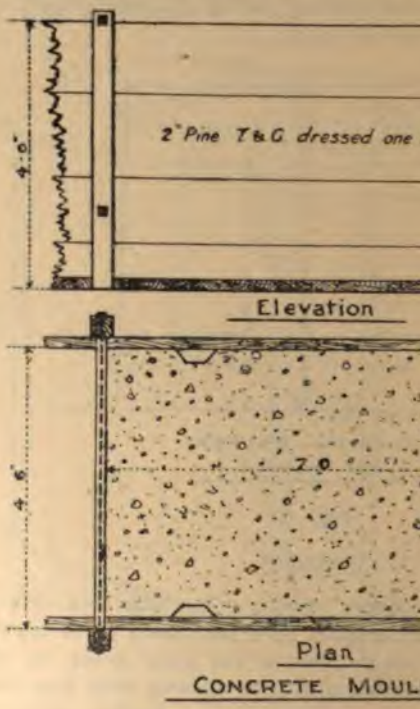
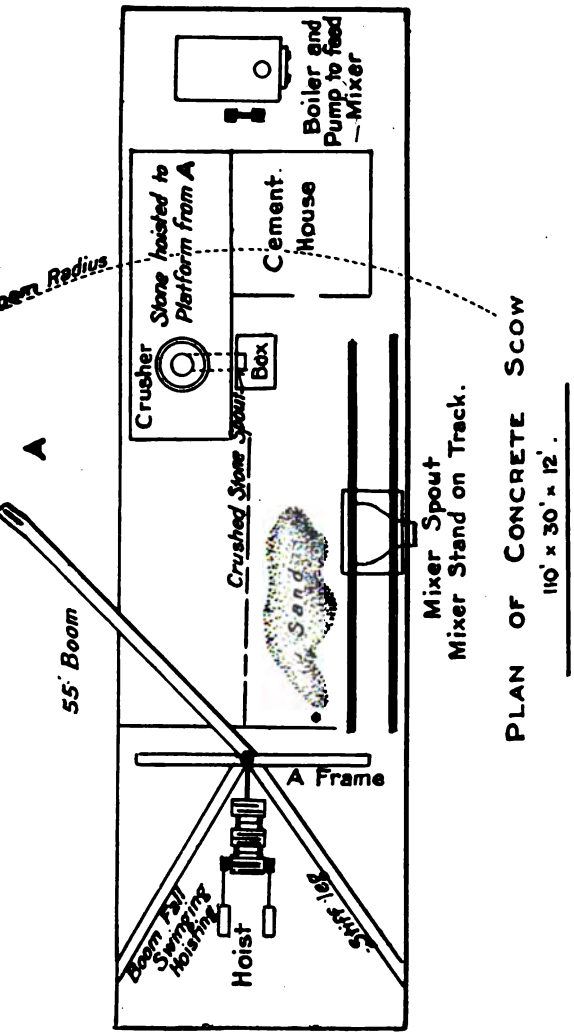


Fig. 8.

The mixer used consists essentially of
ing small iron rods placed perpendicular t
tumbling or turning over motion to the
pipe, controlled by a valve sprays water ov
passes. A door at the bottom of spout is
also controls the water. The door is ke
chamber of the spout is filled, when the
the door closed for another batch, or abou

arger boiler on the scow provided steam for hoist, crusher gine, and small pump, which fed water to the mixer.

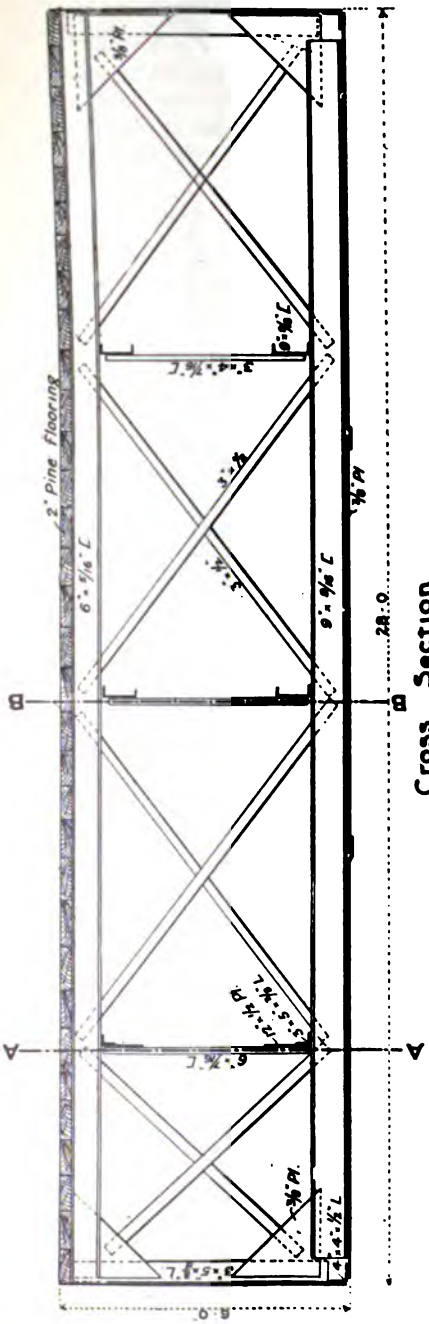
average day's work consisted of 65 to 75 yards for a gang



PLAN OF CONCRETE SCOW
110' × 30' × 12'.

Fig. 9.

talians, forman and hoistman, or about 50 cents per yard for . Cement used (at least 40,000 barrels to date) was Rath-Star," made in Deseronto, Ontario, and the results obtained been excellent.



Cross Section
DRILL BOAT "VOLCANIC"

e mixer moved on tracks, and both could be lifted off and on a wall within radius of boom, and the concrete process as before. Such a method was used in laying the concrete vering of the docks.

Excavation.

e principal item of this part of the work consisted of the , blasting and dredging of 300,000 cubic yards of very hard mestone over a great area. The above quantity is in place, w measurement. The cut varied from 6″ to 6′ but to get o grade it was necessary to drill and blast to 2′ or 3′ below de line to avoid pinnacles and ledges being left. No pay- allowed, however, for this extra depth. Owing to constant ptions by storms this has been the most troublesome part of k.

Drilling and Blasting.

drill and blast, a submarine drill boat is used, consisting ecially strong hull, steel preferably, housed over and carry- boiler, large steam pump drill frames, drills and hydraulic same.

e latest type used at Port Colborne, and built in 1903, con- steel hull 100′ x 27′ x 6′ of ⅜″ plate (see Figure 10) having nd longitudinal trusses composed of channels and bracing. be noticed that the drill frame side is specially strengthened tening the panel length in cross section so that the panel mes under the drill frame, and also by the use of ½″ x 12″ nd bracing longitudinally. The stresses are here a maxi- wing to constant pounding of drills and the impact of the nderneath. The boat is pinned up, i.e., part of her weight, 60 tons, taken on oak spuds 14″ x 16″ at each corner. She held in place. These spuds run in guides and have cast cking sunk even with their face on inner side. A gear attached to slides works in this racking and lowers or puds. A single upright engine operates a series of shafting leck which connects by a sprocket wheel and chain to the heel working in the racking. This method of pinning up is red preferable to an engine on each spud where winter to be done.

e drill proper is attached to a carriage composed of two latticed, and having a saddle at the top. This carriage on two uprights, i.e., the drill frame. An hydraulic ram, g between these uprights and attached to the saddle takes ce of the hand feed on land drills. This ram is controlled ree-way valve, by which the drill carriage is lowered or and, of course, the drill with it. A duplex force pump, to

which is attached a governor to control the
requirements, supplies hydraulic power for t
works against a constant pressure of 300". T
steel to form a cutting end. The drill having
steam similar to a land drill.

Three drill frames are mounted on the b
moved by ratchet and level attached to the a
wheel.

To load holes a cylinder is used having a
the hole and of sufficient length to admit t
This cylinder is slotted on one side to insert
ing wire. To cylinder is attached a long piec
ing well above the water. The drill bar bein
paratus is put down into the hole and a lo
through the pipe, forces the cartridge from th
hole. The loading apparatus is then withdr
ploded by battery. From two to four drills ca
scow, depending on its dimensions. Three
employed steadily on this work for the last fe
vary with the number of drills, a 3-drill ma
including blacksmiths.

Dynamite of 70% strength (as against 40
required for this work. Holes placed 6' apart
lbs. to an 8' hole gives best results. The
sticks 1¾" diameter and 3' long, a stick w
shock from a blast in 16' of water is quite

The following data compiled by the writ
ports, etc., show the results accomplished by
the five months from April to August, 1904.
stant storms, which drive the boats from the
of time in getting back on said ranges, the
measure of the actual capacity of the boat.

	Days of 12 hrs. worked	Holes.	F dr
April..	49	2282	10
May..	43	1348	6
June..	50	1453	8
July..	43	1512	6
August	43	1348	6

Days worked included the time to set up o
the drill was on the range, but could not drill
Night and day crews were worked. The tim
the canal basin weather-bound is not includ
The month of April shows larger results bec
in a sheltered position in the canal. The de

CRIB-BUILDING.

CRIB-LAUNCHING.

e little difference to average result as seen from June and ecords, the depth of drilling in the former month being in of the latter. A deep hole requires an extra drill bar which ime to insert, and deep drilling is also troublesome on of binding, etc., but this is off-set by the extra blasting in er drilling, and loss of time in starting holes.

e best performance, as indicated by the record, was the drill-323 holes, or 1,615 feet, in 72 hours, day work, from April 9th, or an average of 22.4 feet per hour, per three drills. ay's work was 315′, or an average of 27′ per hour.

Dredging.

e dredges used to dig this rock are of recent construction. 2 and 1904, and possess great power. The hulls are of steel te at sides and 1″ at bow. The dredge is pinned up on two l spuds of 36″ x 36″ British Columbia fir running in slides. spuds form the front corners of the hull, which gives a clear ith no projections to be knocked off. At the stern (scow) a single spud 20″ square placed in centre of boat, and at an to the vertical holds boat up against the bank, and ts swinging. This spud is geared similar to drill spuds, as a separate engine, while forward spuds are operated h of the machinery Kelsons, which instead of being small I-box girders, consist of a stiff truss the depth of hull and d to deck channels above, as well as to floor or bottom of This greatly stiffens the vulnerable part of the boat, the nd prevents working of Kelsons under the pull of the en-and consequent opening of bottom and bow plates. Another is the carrying of the overhead truss the full length of the hus affording a secure fastening of the stern anchor and a distribution of the stress it exerts, besides adding to the l stiffness.

e power is got from two 18 x 20 horizontal engines fed by Marine Boiler 11′ x 13′, furnishing 140 lb pressure. A small on the engine shaft operates a larger pinion on a shaft, to ds of which are attached two more small pinions operating in hoisting drum, which is 8′ in diameter. The first series ting is extended in bearings to the sides of the boat, and has ed to it the drums for lifting spuds. When the boat is pinned se drums are thrown out of gear and the spuds held up by n brake, operated on deck by the crew. To lower away the it is only necessary to slack the friction brake.

e hoisting cable is of 2¼″ wire rope, and the life of a cable ging rock with these powerful dredges is not over two s. The dredges are of the single whip variety, no system

of pulleys or blocks being used on crane to
single line of cable from drum to bucket.
1¾" wire rope, while a special engine and
for swinging.

These dredges operate a three yard buck
yard bucket in clay or soft digging.
vary greatly, for the frequent hauling of dr
safety causes many undrilled areas of small
difficult and almost solid rock dredging. A
day is sometimes got. Tests taken of the ne
drilled material loaded in skips of five yards
output of 4,385 cubic yards in six days of tw
ing five hours delay for repairs, this gives an
cubic yards an hour. No effort was made fo
performance was about 1,000 yards (in tubs)
are rock figures, the dredges never ha
soft material.

The excavated material is loaded in
according to the purpose for which it is re
be done by dump scows in less than 7' of wa
a large A frame steel derrick with 65' boom
tons, was built. To carry this a special sco
built, having steel trusses, etc. Owing to its
it was possible to lift to the capacity of the
pinning-up apparatus.

While this derrick was an experiment it
being easier to handle and tow than a regular
sides requiring no time to pin up, it provide
carrying materials.

These works are now almost completed.
ting in foundations for a 2,000,000 bushel ele
sideration, and with the erection of this ele
will possess a harbour equal to the best.

The work has been done by contract
caused principally by the prevalent weather
arose rapidly, and the drills, dredges and sco
their exposed position in the lake into the bas
and drill boats were sunk, and cribs wrecke
With the completion of the two breakwaters,
have perfect shelter.

DISCUSSION.

Mr. Henry Goldmark wished to ask the author whether the Mr. Goldmark.
ıcrete slabs referred to, had been put in place over the concrete
lls, and if so, whether any trouble had been experienced from
cking.

The author replied that they had been put into service, and as Mr. Hogan.
no trouble had been experienced from cracking. They had
y been in service about a year, however.

The chairman considered 65 to 75 yards of concrete per day, Mr. MacPherson.
mentioned in the paper, a pretty good record for 18 men.

With reference to the 75% dynamite, Mr. E. McG. Quirk Mr. Quirk.
shed to know whether any other strength of dynamite or any
ıer form of explosive was used, and whether there were any
ıilable data with regard to the ratio of the cubic yards moved,
pound of explosive? Also, with regard to the 65 to 75 cubic
rds per day, whether this was quantity of rock as measured in
ce, or in the loose?

Mr. Hogan replied that the only strength of dynamite used was Mr. Hogan.
%. In regard to the 65 to 75 cubic yards per day,—this was
w measurement.

Dr. J. B. Porter thought it was the present practice in most Dr. Porter.
omarine work to use 75% dynamite. Some little time ago an
gineer in charge of an important harbor improvement had told
n that in all his work 75% dynamite was used when working
der water, and it was found that it was more satisfactory than
veaker percentage. He believed the lower percentage dynamite
s very seldom used under water.

Mr. W. J. Sproule said he considered the paper a very interest- Mr. Sproule.
; description of an enormous piece of work. He would not
empt to discuss the work in its different aspects, but wished to
ke a few remarks in connection with the drilling and blasting.
e paper stated that for drilling and blasting a sub-marine drill
ıt was used, consisting of an especially strong hull, steel prefer-
y, housed over and carrying the boiler, large steam pump drill
mes, drills and hydraulic feed for same. The Montreal Harbor
mmissioners had a drill boat, built by themselves, of wood
irely, 80 feet long and 27 feet wide. This drill boat had been do-
; some very heavy work, had three drills working, and had done
rk as deep as 42 feet. 75% glycerine had often been used, and
pection had shown that the drill boat was very slightly affected
the work. The drill boat mentioned in the paper was of steel,
ile the Montreal boat was of wood. The former was especially

Mr Sproule. strong on the drill side, while the latter was fle
stated that the wooden scows were opened by
that a charge at 16′ was quite perceptible. That
at an even greater depth. As he had stated, this
structed especially weak on the drill side, an
theory that it should be as flexible as pos
would give to the force of the explosions. The
side and the machinery, coal bunks, etc., on th
side was stiff to keep the boat from shaking. T
been in use nearly ten years, and had not been
than any others of the harbor fleet. In fact it
faction in every respect, and even in drilling
feet of water with the drill perhaps 15 feet in
little damage, and though a cheap structure, had
excellently." The manner in which it had sto
really a surprise to those in charge, as they had
would be more or less scarred and knocked ab
well for the author to investigate this point a l
it was a question whether or not the steel hull

Mr. Hogan. Mr. Hogan thought that he had conveyed a
There were two drill boats in use prior to the i
one mentioned in the paper, and they were not
factory for the class of drilling. This led to t
the steel hull, and it had been a very great suc
been working for two years, night and day, and
been found. The latest drilling boats in Buffal
and were very highly thought of there. Wher
would require to be calked, the steel hull could si
which is a great deal less trouble than calking.
were encountered on the great lakes which had n
against here.

Mr. Mountain. Mr. G. A. Mountain wished to know wheth
Colborne work was built in concrete blocks, or
Crib work was used on part of it. Mr. Fraser
engineers of the Public Works Department. Mo
would remember that he was unfortunately dro
Loup. He invented the crib-work called Fra
work, which consisted of moulded timber 12 x 12
inforced with ¾″ iron, the whole fastened tge
bolts. The idea was that it was cheaper than t
and it was filled in just similar to ordinary tim
quantity of concrete required was a great deal les
had been given to understand it was to be tried
which caused him to raise the question. He now
was to be tried in the Eastern breakwater. The
of course, was to cheapen the cost of the struct

nd yet do permanent work. He had heard that this work as also to be tried at Depot Harbor, the work in which he had een interested previously, but he had not heard of results from ere. He had seen the moulded timbers, but had never seen em put together. If the scheme would work, he thought there ight to be about a 50% saving in concrete.

Mr. D. MacPherson asked if it would not be more expensive make than concrete blocks. Mr. MacPherson.

Mr. Mountain thought it would. Another point which struck m was, that when the large steamers struck the concrete, there ight be a tendency to crack it. However, the manner in which great many cribs have been built has been simply money thrown way, and the patent crib-work ought to be an improvement. Mr. Mountain.

ELECTRICAL SECTION.

President—R. B. Owens.
Vice-President—W. McLea Walbank

Meeting Thursday, March 9th, 1905, to hear
paper. Dr. R. B. Owens was in the chair:—

PAPER No. 225.

INTERFERENCE IN WIRELESS TELEGR

By John Stone Stone.

Introduction.

Of the various problems which have been pr
course of the development of the new art of wire
none is of greater interest to the engineer and none
reaching importance from the industrial and comme
than that of rendering the receiving instruments o
graph stations immune from *interference*.

There are two principal kinds of interference.

1st. Interference which arises from electrica
accumulate upon the vertical oscillator
conditions of weather, provided the ve
has no adequate electrical connection to

2nd. Interference which arises from such
magnetic waves as are produced by
magnetic storms, by sparks in neigh
such for instance as occur in trolley ci
from the electromagnetic waves emanat
less telegraph stations other than th
communication is desired.

Interference Due to Static Charges.

The interference which results from the first of these two sources is readily overcome since the oscillator of a wireless receiving station may always be given a metallic connection to the earth sufficient to maintain it clear of statical charges without in any appreciable degree interfering with its operation as a receiving oscillator.

Thus for instance if the vertical oscillator includes a condenser insulating a portion of the vertical oscillator from the earth, the condenser may be shunted by a coil of inductance so large that

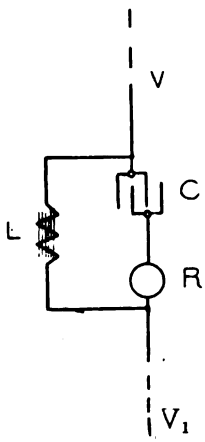


Fig 1.

for the high frequencies employed in wireless telegraphy it will operate practically as an open circuit, whilst affording a ready path to earth for the electrical charges which, in its absence, would accumulate upon the vertical oscillator and produce disruptive discharges to earth.

Again, if a highly sensitive detector or receiving device be included directly in the vertical receiving oscillator, such an inductance coil may be placed in shunt to the receiver without appreciably affecting its sensitiveness. The coil will then serve as a by-path for the currents due to the passage of the charges of the vertical oscillator to the earth.

Another device which may serve to still further protect the receiver under these conditions is that illustrated in Fig. 1, in which

V and V_1 are portions of the vertical oscillator sy
of large inductance, R is the receiving device, and
of capacity so large as not to impede appreciabl
the high-frequency oscillations of wireless telegra
practically as an open circuit for the more slowly
by which the vertical oscillator is maintained free

The greatest security from this form of inte
ever obtained by providing the vertical receivin
an adequate conductive connection to earth and
receiving device in a local circuit made resonant
condenser to the frequency of the electrical oscil
the receiver is intended to respond.

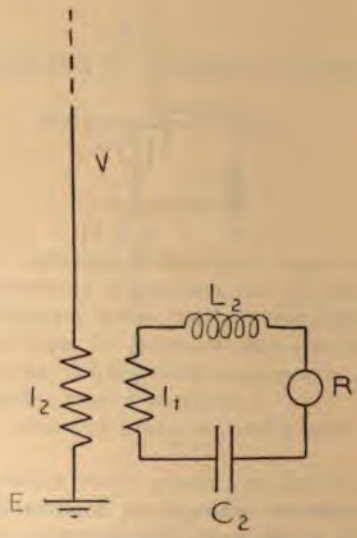


Fig 2

An example of such an arrangement is show
which VI_2E is the vertical receiving oscillator, I_1
two coils of a high frequency transformer, R is
is a condenser and L_2 is an inductance coil.

The manner in which the local circuit contai
is made resonant to the frequency of the oscillatio
intended to respond will be considered later in t

cient here to note that the local circuit being resonant to a uency sufficiently high for the purposes of wireless telegraphy, not be appreciably affected by the more slowly varying currents he vertical oscillator by which the latter is maintained free static charges.

Interference due to Electromagnetic Waves.

Coming now to the prevention of interference by electro-netic waves such as emanate from other wireless stations than with which it is desired to hold communication, and to the ention of interference by stray electromagnetic waves, we find the solution of the problem depends upon the character of message-bearing wave, the energy of which it is desired to ey to the receiving device, and also upon the character of the rbing waves, the energy of which it is desired to exclude or rt from the receiving device.

We can control the character of the waves whose energy we to receive, by suitably designing the apparatus to be used he transmitting station, but we have no control over the acter of the disturbing waves except in so far as these arise wireless stations within operative range of the receiving sta-

The simplest solution of this problem is to cause each trans-er to send out its signals by means of *persistent trains of simple onic waves* of a frequency materially different from that loyed by any other transmitter within operative range of the iving station with which communication is to be maintained to make each receiver responsive only to *persistent trains of le harmonic waves* of the frequency employed by the transmitter which it is in communication.

By this means the system is rendered selective and becomes a tiple system of telegraphy, permitting the operator at each ion to select the station with which he wishes to hold com-ication to the exclusion of all the other stations, and by which umber of messages may be transmitted simultaneously in a n region without interfering with one another.

Since the stray electromagnetic waves arising from lightning are not persistent trains of simple harmonic waves, but partake e of the character of isolated impulses, the receiver in such a em does not respond to such stray electromagnetic waves and s therefore also freed from interference which would otherwise e from such sources.

The manner in which a transmitting station is made to de-p persistent trains of simple harmonic electromagnetic waves

of one frequency to the exclusion of waves o
though simple in itself, in practice requires th
to certain details, and these may be best unders
ration of a concrete case, this being the ma
problems are usually presented to the engineer i

Transmitter.

In modern wireless telegraphy the messag
by electromagnetic waves which are horizonta
earth's surface, and which are developed by e
set up in an electrical oscillator whose axis is
face of the earth and which is connected to th
extremity.

The reason for employing waves of this
oped, is that such waves have, at the earth's su
of electric force parallel to the surface and n
magnetic force normal to or cutting that sur
immediate neighborhood of the base of the tra
As a result they do not tend to induce current
the earth as they travel away from the transm
the surface of the earth deviates from the plan
the waves at that surface. The energy which
rapidly dissipated through the production of
the earth is therefore conserved in the waves.
deviation occurs between the plane of the eart
plane of polarization of the waves at the e
currents induced in the surface of the earth a
the wave front into a position normal to the sur
that the waves travel over and around mountain
the earth's surface whatever be its contour, in
travel in straight lines like ordinary light wav
the case with vertically polarized electromagne

For a more complete exposition of these poi
by the Author at the International Electrical C
Louis, Sept. 12 to 17, 1904, and reprinted in the
New York, Oct. 15, 1904.

There is not space in this paper to discus
velopment of the waves described above, but
mode of propagation is clearly suggested by F
and Fig. 4 illustrate the development of a wav
oscillations in a straight wire AoB, the curved
line of electric force in its various phases fro
where T is the time of a complete free electrica

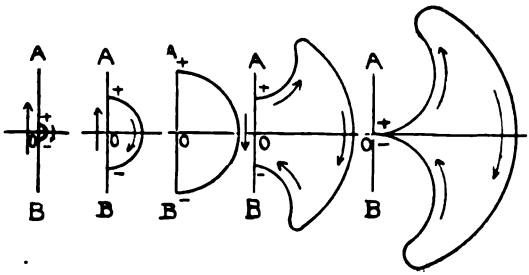


Fig. 3

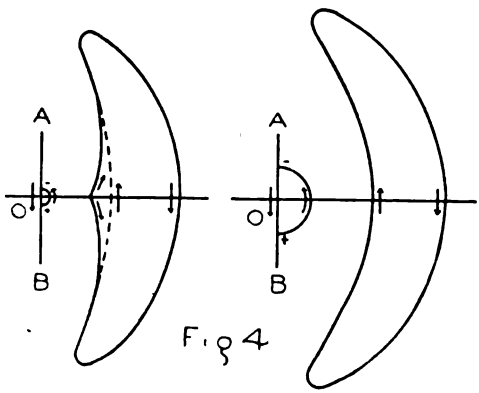


Fig 4

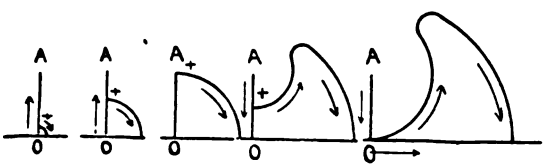


Fig. 5

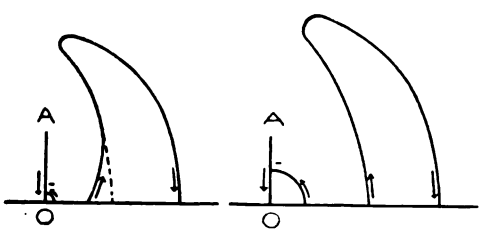


Fig. 6.

wire. In Figs. 5 and 6 the genesis of a wave fro
oscillator Ao earthed at its lower extremity is
.Figs. 7 and 8 the effect of an elevation and dep
face of the earth upon the wave fronts at that s

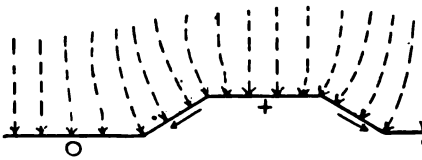


Fig 7

We may next consider the earth connection
oscillator and the nature of the support for th

Although, by the use of such waves as a
normally the current density in the surface of
tance from the transmitting oscillator is re
small, nevertheless at, and in the immediate n
base of the vertical oscillator, the current densit
great. Moreover since the current is of high
to flow only on the surface of the earth. For th

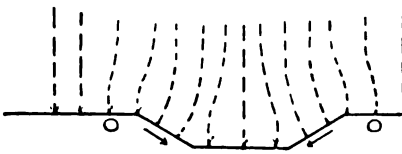


Fig 8

specifications for obtaining a good earth connec
burying a conductor of large area so deep in
shall be in permanently moist earth, are no l
and in a properly constructed wireless tele
conductivity of the *surface of the earth* in the i
hood of the base of the oscillator is artificia
superficial ground-plate composed of sheet metal,
extending radially from the base of the oscilla
large an area about the base of the oscillator
the purpose and consistent with reasonable eco

Since the waves are horizontally polarized, the supports for the vertical oscillator, such as masts and guy-ropes, should either be of insulating material, or if of metal, they should be divided by insulation into sections short compared to one-half the wave-length of any of the waves to be employed. The reason for this is that the fundamental free period of vibration of a linear conductor is such as to cause it to respond most energetically to waves of twice its own length. For such wave-lengths, therefore, the linear conductor would absorb an undue amount of the energy of the waves and moreover because of the rise of potential which occurs at the ends of the conductor for waves of such length it would be difficult to insulate the conductor from the earth or adjacent portions of the support of the vertical oscillator.

We come now to the vertical oscillator itself. This in general consists of two parts, the elevated conductor *per se* and the devices through which it is connected with the earth.

We shall here consider the relatively simple case in which the elevated conductor is a straight, cylindrical copper wire of length a and radius ρ

Both theory and practice show that the electrical vibrations in such a wire connected directly to the earth at its lower extremity correspond very closely to the transverse vibrations of a heavily damped stretched string.

If such a wire be charged to a high potential and be then permitted to discharge to earth, the electrical oscillations developed in it, and therefore also the electromagnetic waves radiated by it will not be simple harmonic in type and will not be persistent. These waves will not therefore correspond to the sound waves given out by a tuning-fork, but will be of the character of those given out by a heavily damped violin string plucked at its centre.

The fundamental of the waves given out by such an oscillator has a wave-length which very closely approximates four times the length of the wire, and this is accompanied by all the odd harmonics. The oscillations are so much damped by the energy drawn off from the oscillator by radiation as to make the resulting waves more nearly the equivalent of an impulse than of a sustained or persistent train of waves.

If, however, the elevated conductor be not directly connected to the earth, but be connected to it through an inductance coil, both theory and practice show that its electrical vibrations correspond to the transverse vibrations of a heavily damped stretched string with a mass attached to its centre.

The effect of the load at the centre of the stretched string and of the inductance at the base of the vertical wire is to increase the

persistency of the vibrations, to minimize the i
harmonics and to lower the frequency of the
might therefore seem that in order to cause the
in question to radiate a persistent train of simpl
of a predetermined frequency, it would be suffici

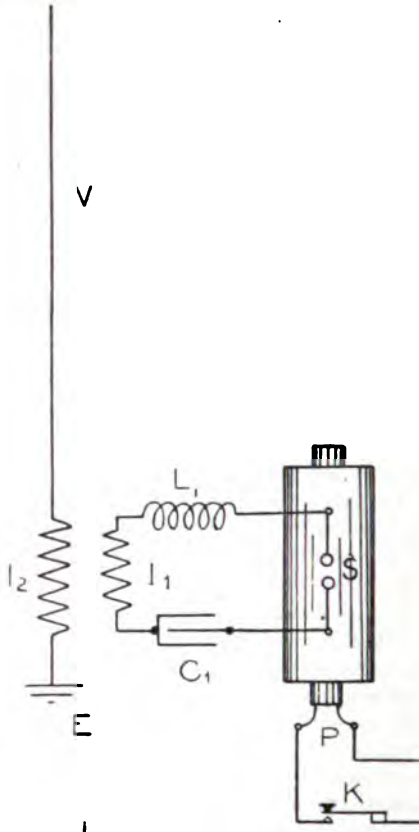


Fig 9

vertical wire to a high potential and permit it to d
through an inductance coil of suitable dimensions.

This indeed was the plan adopted in the firs
at producing a selective system of wireless telegrap
necessitates the use of waves of much lower fre
normally produced by natural vibrations in the ve

The degree of persistency of oscillations so obtained, however, ot as great as is required in practice. Such persistency as is ned is gained at the expense of the amplitude of the current lations in the vertical and at the expense of the radiating r of the oscillator, the latter being *caeteris paribus* less for than for high frequencies. Moreover the spark in the vertical lator which normally dissipates an undue amount of the energy e oscillations, has its resistance enhanced by the reduction of mplitude of the current oscillations due to the presence of the ctance coil.

This latter difficulty may in a measure be overcome at the nse of any increase of the energy supplied to the oscillator, hunting the spark gap by a condenser of large capacity. The harge of the condenser across the spark gap increases the ent through the spark and thereby reduces its resistance and ping effect upon the oscillations. The damping effect of the ation still remains and the persistency is still too much lim- for practical purposes.

So far we have considered only the *natural oscillations* of the cal oscillator which are produced by charging the elevated uctor to a high potential and then permitting it to discharge arth. When, however, a high degree of persistency, a pure wave and a great amplitude of oscillation are desired, the k gap is removed from the vertical oscillating circuit and a le harmonic electromotive force is impressed upon the ver- oscillator in its place. The resulting vibrations in the ver- oscillator are then *forced simple harmonic vibrations.* In order they may be of great amplitude, the frequency of the essed force is made to correspond to the fundamental of the ical oscillator or to one of its harmonics, in which cases the tance of the vertical oscillator is nil.

A simple arrangement for producing forced, simple harmon- ibrations in the vertical oscillator is shown in Fig. 9 in which an alternating current generator, k is a key, P shows the ection to the terminals of the primary of a spark coil, S is a k gap between the terminals of the secondary of the spark C_1 is a condenser, L_1 is an inductance, I_1 and I_2 are the ary and secondary coils of a high-frequency transformer, V e vertical wire and E is the earth.

There is a variety of ways in which substantially the same lt may be accomplished, but there is not space in this paper onsider more than one arrangement.

or the type of elevated conductor which we are here considering a cylindrical copper wire of length a and radius ρ the reactance

of the elevated conductor *per se* is given wit
approximation ample for engineering calculatio
pression;—

$$Z = -Lv \cot \frac{na}{v}$$

where $L = 2 \log_e \frac{4a}{\rho} - k$

and where $k = 5{\cdot}584 - 3{\cdot}169\left(\frac{na}{v}\right)^2 + 0{\cdot}3269\left(\frac{na}{v}\right)^4$ for valu

0 and $\frac{\pi v}{2n}$

In these expressions v is the velocity of l[1]g
periodicity of the impressed force or $\frac{2\pi}{T}$ where
a complete oscillation.

The reactance Z therefore vanishes when n =
m is an odd integer. The wave lengths corres
condition are therefore $\lambda = vT = \frac{4a}{m}$. The wa
fundamental is therefore 4a and the harmonics ar

For frequencies lower than the fundamenta
is negative or a capacity reactance. For frequenc
of the fundamental and its first harmonic the r
itive or an inductance reactance. For frequenci
of the first even harmonic and the first odd harmo
is again negative or a capacity reactance. In othe
actance of the vertical wire measured at the sc
point of the system is either that of a condenser of
$\tan \frac{na}{v}$ or of an inductance $L' = \frac{Lv}{n} \cot \frac{na}{v}$
whether $\cot \frac{an}{v}$ is positive or negative.

The condition for zero reactance in the v
system is obviously $Z + Z_0 = 0$ where Z_0 is the
apparatus connected between the vertical wire and
must therefore be an inductance reactance for fr
make the reactance of the vertical wire a capacit

(1) The value of k here given has been determined empirically,
formula being based upon a theoretically deduced working theory
eferred to on page 133. A more complete expression for L will be give

sely it must be a capacity reactance for frequencies which he reactance of the vertical wire an inductance reactance.

e curve shown in Fig. 10 gives the observed apparent y of vertical wires 0″.08 in diameter varying from 40 to t in length, when the periodicity of the impressed force is 10^6. In other words it gives the observed apparent capacity ical wires for values the angle of $\frac{na}{v}$ from 0.3976 to 1.790 values of the ratio $\frac{4a}{\rho}$ from 47,520 to 213.800.

e reactance Z_0 of the apparatus through which the ver- ire is connected to ground may most simply be made

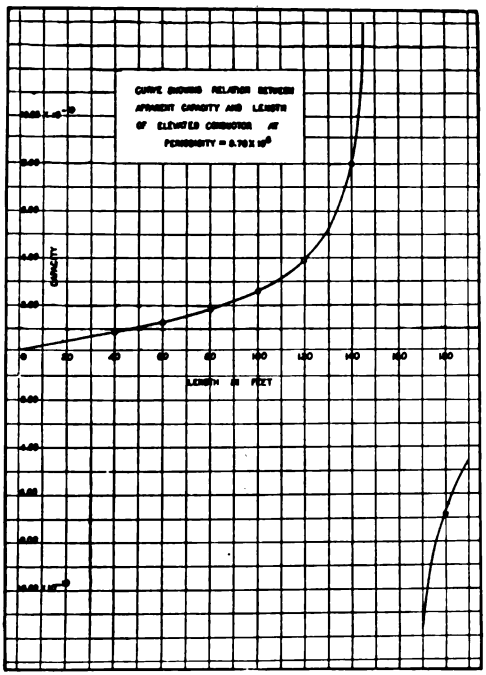


Figure 10.

ve, when this is necessary, by the insertion of a condenser es with the coil I_2, but this result may be accomplished in ety of ways for the description of which there is not space paper.

will be seen that by making $Z + Z_0 = 0$, or Z_0 equal, but te in sign to the reactance of the elevated conductor, powerful

oscillations of any desired frequency may be
vertical oscillator by means of forced vibratio
the natural oscillations of the vertical oscillator
frequency must necessarily be less than that
of the oscillator.

Concerning the arrangement illustrated in
much of detail which requires attention in order
shall satisfactorily fulfil the requirements of
sistent train of simple harmonic waves. F
dielectric having considerable electrostatic hyst
in the condenser, a surprisingly large amount
dissipated in this dielectric. The magnitude of
the fact that the energy dissipated increases both
difference employed at the terminals of the c
with the frequency. Since potential differences
terminals of the condenser amounting to 50,000
tions having frequencies of 5,000,000, are not u
telegraphy, it is easy to see that the losses in
condenser in a wireless telegraph circuit are of
than that in the dielectric of condensers empl
power or lighting circuits.

Moreover the specific inductive capacity of
a function of the density of the displacemen
dielectric, and when such dielectrics are employe
in an oscillating circuit the resulting oscillatio
harmonic in form and are not isochronous thr

Air condensers should therefore be used in
to the exclusion of any other type pending the
results of certain investigations which are bei
the view of supplying a dielectric of high diele
constant specific inductive capacity.

The coils used in wireless telegraphy shou
cores except the iron be very finely comminute
a non-hygroscopic dielectric matrix. It has even
author that coils wound on a wooden cylind
satisfactorily when used in the oscillating circuit
raphy. The coils for this purpose are best const
a few turns of bare copper wire in a single la
frame made of ebonite, care being taken to sep
such an amount that the sum of the air spaces
of the turns is equal to or slightly greater
distance in air corresponding to the greatest
liable to occur at the terminals of the coil whe
in operation.

ie local oscillating circuit C_1 I_1 L_1 S of the arrangement n Fig. 9 were isolated, its oscillations would be expressed

$$= \frac{e}{L} \frac{1}{\sqrt{\frac{1}{LS} - \frac{R^2}{4L^2}}} \epsilon^{-\frac{R}{2L}t} \cdot \sin \sqrt{\frac{1}{LS} - \frac{R^2}{4L^2}}$$ where i

urrent, e is the potential to which the condenser C_1 is at the time when the spark occurs at S, L is the inductance circuit, R is the resistance and S is the permittance or atic capacity of the condenser.

e oscillator is at all persistent $\frac{R^2}{4L^2}$ is negligible compared

, and the expression reduces to

$$= e \sqrt{\frac{S}{L}} \epsilon^{-\frac{R}{2L}} \cdot \sin \frac{t}{\sqrt{LS}}$$

time required to fall to $\frac{1}{\epsilon}$ th of their initial amplitude is

$$t = \frac{2L}{R}$$

number of oscillations per unit of time is $\frac{1}{2\pi \sqrt{LS}}$

measure of the persistency of the circuit is therefore

onal to $\sqrt{\frac{L}{R^2S}}$

a given frequency, $Ln = \frac{I}{Sn}$ so that the persistency given frequency is proportional to $\frac{Ln}{R}$, where n is the frequency.

isolated circuit of this type may be made to give extremely nt simple harmonic oscillations, but if it be given a large ent of mutual induction with another oscillator of y low persistency, such as the vertical oscillator VI_2E of angement shown in Fig. 9, two things happen. In the first e oscillations of the circuit are in general no longer simple ic, but are broken up into two simple harmonic oscillations rent frequencies, and in the second place the persistency is reduced.

To overcome this difficulty it is necess
magnetic leakage of the high frequency t
the local oscillating circuit with the vertic
large, or else to add to the local oscillatin
coil L_1 with sufficient inductance to swamp
tion from the secondary circuit.

When intense radiation is desired, it
the capacity S of the condenser C_1 in the
large compared to S′ the apparent capacity
or *per se*, for the frequency employed.

Receiver.

Since the electromagnetic waves to be
telegraph receiving station are horizontally
surface, an electrical oscillator whose axis i
surface is employed at the receiving statio
either be connected to earth at its lower e
connected to a device having reactance eq
to the reactance of the vertical oscillator. It
this regard that at the receiving station
with what becomes of the energy which is
radiation of the energy from the receiving v

We shall consider again a simple co
assume the elevated conductor to be a cyli
length a and radius ρ as in the case of the
must by no means be assumed that the ele
receiving station must necessarily be sim
transmitting station, or, in fact, that it m
blance to that at the transmitting station
axis is preferably normal to the surface of

As in the case of the transmitting sta
arrangement of the apparatus sufficient to
will here be considered. By this arrangeme
ted by means of persistent trains of sim
magnetic waves of a predetermined frequen
the exclusion of messages transmitted by si
ially different frequencies, and without inte
waves. Such an arrangement of the circ
shown in the diagram 11. In this arran
device which is indicated at R is placed in
L_3 R which is made reasonant to the freq
which the station is intended to respond, a
circuit C_2 I_2 L_2 I_2' reasonant to the same f
"weeding-out circuit", is interposed betwee
circuit and the vertical oscillator.

ranch circuit consisting of the coil I_1, and condenser C_1 hen taken by itself, reasonant to the same frequency as local circuits, but is so proportioned that when con- a branch circuit, forming a part of the vertical oscillator he latter shall respond most energetically to persistent waves of that frequency falling upon the vertical wire. ray in which this is accomplished is perhaps more easily graphical demonstration than by the use of the analytical though the latter is by no means difficult.

urves in Fig. 1 illustrate the point in question. Curve 1 the reactance of the vertical wire measured at its point ment to the loop circuit, for varying periodicities of the

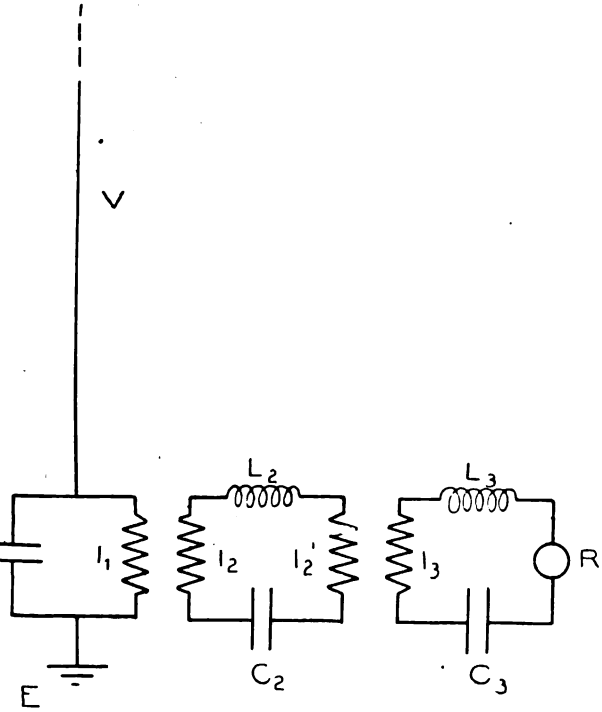


Fig 11

l force. It will be seen that the periodicity of the ntal of the vertical wire is at the point n_1'', where the e first vanishes. The first even harmonic is at n_2'', and odicity of its first odd harmonic is at n_3'', where the

reactance again vanishes. Normally therefo current curve for varying periodicities of the vertical wire would show maxima at n_1'' ance of the loop circuit for varying period force, measured across the points of its att wire and earth connection is shown in Curve 2 the vertical oscillator measured at the e algebraic sum of the two reactances shown as a result the current curve 3 shows ma n_3'', but at periodicities n, n″ and at a per than n_3''.

These are the points at which the react is equal, but opposite in sign, to that of the

The periodicity of the local loop circui this periodicity the current in the vertical

The "weeding-out circuit" and the receiver are both resonant to the periodic sistent trains of waves of that periodicit oscillations set up in the vertical oscillator to the receiver, but persistent trains of wav either produced by slight response in the else produced oscillations of the periodicit city slightly higher than n_1'' have little effe such periodicities the "weeding-out circuit taining the receiver are extremely irrespon ing device receives but an inappreciable an the waves.

In the case of impulsive waves the respond only to its own natural rates of the loop circuit, that is to say, it tends to n″ and to upper harmonics. Such waves wire, have little tendency to develop osci period of the loop circuit as affected by vertical wire, namely n, and the receiver is from the effects of such impulsive waves.

All that has been said regarding the eff magnetic hysteresis in the description of t applies with added force to the apparatus a It is, in fact, much more important to hysteresis from the receiving circuits than circuits, and it may be laid down as an im no circumstances shall solid or liquid diel receiving circuits.

reover the injuction in regard to making the mutual in-
ce small between oscillators at the transmitting station
in the case of the resonant circuits at the receiving station,
f the mutual energies of the related resonant circuits be
all compared to their self energies, the resonant circuits
odify one another's natural periods and each circuit will
d to more than one periodicity.

ally it may be said the measure of the selectivity of a
nt circuit is proportional to $\sqrt{\frac{L}{R^2S}}$, this expression
the same as that found in connection with the persistency
oscillating circuit. For a given periodicity, therefore, the
ity is proportional to $\frac{Ln}{R}$

great is the selectivity of resonant circuits constructed of
ndensers and properly designed inductance coils that there
difficulty in adjusting such circuits to resonance for a given
ncy with an error of less than one part in 3,000.

e importance of the "weeding-out circuit" in the receiving
becomes apparent when we observe that the selectivity of
ceiving vertical oscillator is greatly diminished by the dis-
n of energy, which results from the re-radiation of energy
t oscillator and that the selectivity of the resonant circuit
ning the receiver may be greatly diminished by the energy
ed by the receiver and utilized in its operation.

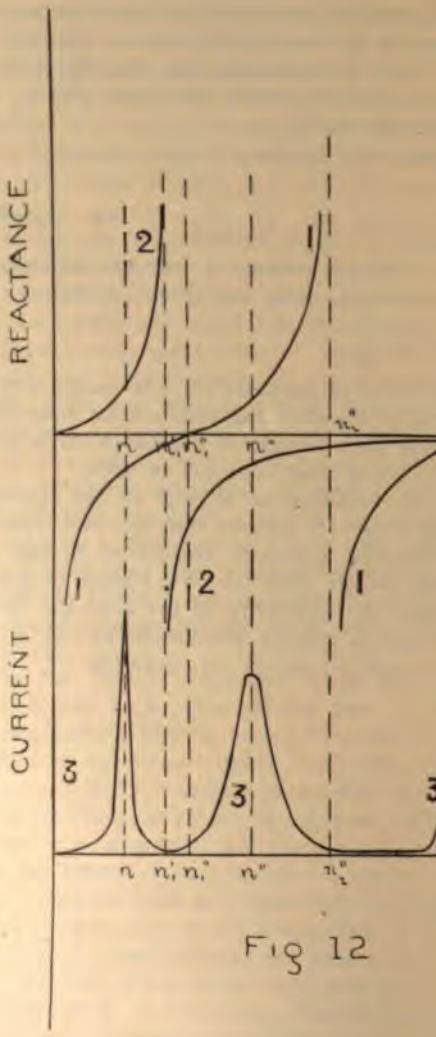


Fig 12

BUSINESS MEETING.

A business meeting for the opening of ballots for the election members was held on Thursday, March 16th, 1905, Mr. Phelps hnson in the chair. Messrs. W. J. Sproule, A. A. Bowman, G. grand, J. A. Jamieson and J. W. Heckman, being appointed utineers, declared the following elected:—

MEMBERS.

J. B. COCHRANE.
V. H. DUPONT.
E. S. FRASER.
J. E. HARDMAN.
J. L. HARRINGTON.
F. T. PEACOCK.

ASSOCIATE MEMBERS.

D. W. BURPEE.
L. M. CAIRNIE.
E. C. H. DOWSON.
A. T. FRASER.
A. J. GAYFER.
R. A. HARRY.
J. P. LECLAIRE.

RANSFERRED FROM CLASS OF ASSOCIATE MEMBER TO CLASS OF MEMBER.

W. D. BAILLAIRGE.
W. W. COLPITTS.
T. R. HENDERSON.
N. J. KER.

RANSFERRED FROM CLASS OF STUDENT TO CLASS OF ASSOCIATE MEMBER.

H. B. CRAIG.
H. M. DIBBLEE.
G. B. HUGHES.
J. H. JACKSON.
Y. D. KIRTON.
R. H. SQUIRE.

STUDENTS.

F. W. ANDERSON.
W. P. BELL.
W. G. B. BROWN.
A. BURNETT.
P. DAVIS.
J. G. DICKINSON.
F. G. DUNNING.
S. E. FARLEY.
H. L. FORBES.
P. R. GRANSAULL.
A. M. HAMILTON.
A. E. HEPBURN.
L. B. KINGSTON.
H. A. LUMSDEN.
G. E. MCCUAIG.
C. H. MCDOUGALL.
G. MCDONALD.
E. E. CLAWSON.
L. H. COLE.
G. E. COLE.
R. P. COWAN.
A. MCMEEKIN.
T. C. MAHON.
E. N. MARTIN.
J. H. H. NICOLLS.
W. R. MOTLEY.
J. F. W. OWEN.
N. F. PEDLEY.
J. G. REID.
H. E. SCOTT.
J. W. SIMARD.
O. M. STITT.
R. A. WEAGANT.
F. G. WICKWARE.

MECHANICAL SECTION.

Meeting Thursday, March 23rd, 1905, Mr. Phe
chair. Mr. W. H. Laurie read the following pa

PAPER No. 226.

GAS AS A MOTIVE POWER, AND ITS REL

By W. H. Laurie, M. Can. Soc. C

Gas was first introduced in the year 1793
illuminating purposes, and the first reciprocatin
introduced one year later by Street, and in 180
was taken out on a gas engine, setting forth th
gained by compressing the gas and air before e
sion cylinder. These two patents embodied two
principles upon the merits of which later engi
practical success, although a period of sixty year
date of these patents before a practical gas mot
even then the consumption of gas per horse-po
cubic feet per hour per horse-power, six or seve
to-day. It was not until 1876 that a really suc
produced by Otto, and from that date the gas
gradually becoming a more serious competit
engine, and has within the last few years reache
has entirely out-distanced the moderate sized st
to the high efficiency obtained from recent im
details of construction together with improveme
tus for generating the gas.

Gas.—Any combustible material, when subj
temperature either by its own combustion, or, b
of external heat, will be partially, or wholly co
There are three principal processes for making
products of which are known respectively as:—

1st.—Illuminating, or coal gas.
2nd.—Water and producer gas.
3rd.—Semi-water gas.

Illuminating Gas.—The first (illuminating,
usually made from bituminous coal, as that cont
centage of volatile matter, and less fixed carbo

being only the volatile matter that is converted into gas, the xed carbon remaining in the retorts in the form of coke.

The coal is placed (in charges from two to four hundred-eight) in fire clay retorts, hermetically sealed, which have been eated to the necessary temperature for gas making (from 1,800 to 000 degrees). The coal is subjected to this heat for a period of ve or six hours, by which time it will have given off all the gas is capable of evolving.

The gas, on leaving the retorts, passes through a pipe leading the hydraulic main, where a portion of the tarry matter is de-osited, and the temperature reduced to about 140 or 150 degrees.

From the hydraulic main it is drawn off into a surface con-enser, where the gas becomes cooled to normal temperature, about degrees, and deposits the tar and aqueous vapor previously held suspension.

From the condenser the gas passes to the exhauster, the func-on of which is to remove the gas from the heated retorts as fast it is produced, and at the same time force it on with sufficient rce to pass it through the various materials used in its purifica-on.

From the exhauster the gas enters the apparatus intended for e abstraction of the ammonia, consisting usually of a scrubber, washer, or both. The function of these devices is to remove all e ammonia and some of the carbonic acid and sulphuretted ydrogen in the gas.

From the scrubbers the gas passes to the purifiers, where the maining impurities—carbonic acid and sulphuretted hydrogen—e abstracted by means of lime and oxide of iron. Under this rocess the following are the approximate results obtained from a n of Newcastle coal, according to an authority on the subject:—

Gas (10,000 feet)..	380 lbs.
Tar (10 gals.)..	115 "
Ammoniacal liquor..	177 "
Coke (absolute)..	1,568 "
	2,240 "

Water Gas.—About 1784, Cavendish discovered that hydrogen, hich had been previously known as "Inflammable Air," was one f the component parts of water, but no practical use was made of e discovery until 1824, when J. H. Ibbetson took out a patent r a special method of making illuminating gas, by passing steam hrough a mass of incandescent carbon; and even then no apparatus as designed that could be considered a commercial success, until bout 40 years after. Among the water gas processes in use to-day,

that of the Loomis-Pettibone is one of the most America.

This plant consists of two generators from f in diameter, and from twelve to eighteen feet in boiler, with necessary valves, etc. The generato firebrick, with firebrick arched grates, ash-pit an the bottom. They are provided with a door on admission of air, two cleaning doors above the below the grate into ash-pit.

The vertical boiler is of the multitubular ty able size to correspond to the generators, and is base with the generators. An exhauster is con top of the boiler beyond the producer valve.

In Operation.

The generators are supplied with a layer of co thick, which is ignited at the top, the exhauster ward draft; when this body of fuel is ignited, c intervals, raising the fuel bed to about eight f and there maintained.

Bituminous coal is generally used and is fed door in the top of the generator. Air is also the same doors and by means of the exhauster through the grates and ash-pits of the generator vertical boiler and then to scrubbers and exhaust is delivered to the gas holder.

When the exhauster has brought the fuel up candescence, the charging doors are closed, and as to direct the flow of gas as desired. Steam is the ash-pit of one generator, and, in passing th descent coal, is decomposed, forming gas. From the gas passes through the connecting pipes sho of the generators, and down through the second into the base of boiler and up through the same, being washed in a scrubber, is passed to gas hol

Water gas is made for about five minutes, w ture of the fuel beds having been considerably r is shut off and the process reversed.

The process of making water and producer at intervals of five minutes or so. In making t water gas the course of the steam is reversed, i turned into the ash-pit of No. 2 generator and do

While the fires are being blasted, and during water gas, the hot gases, in passing through the

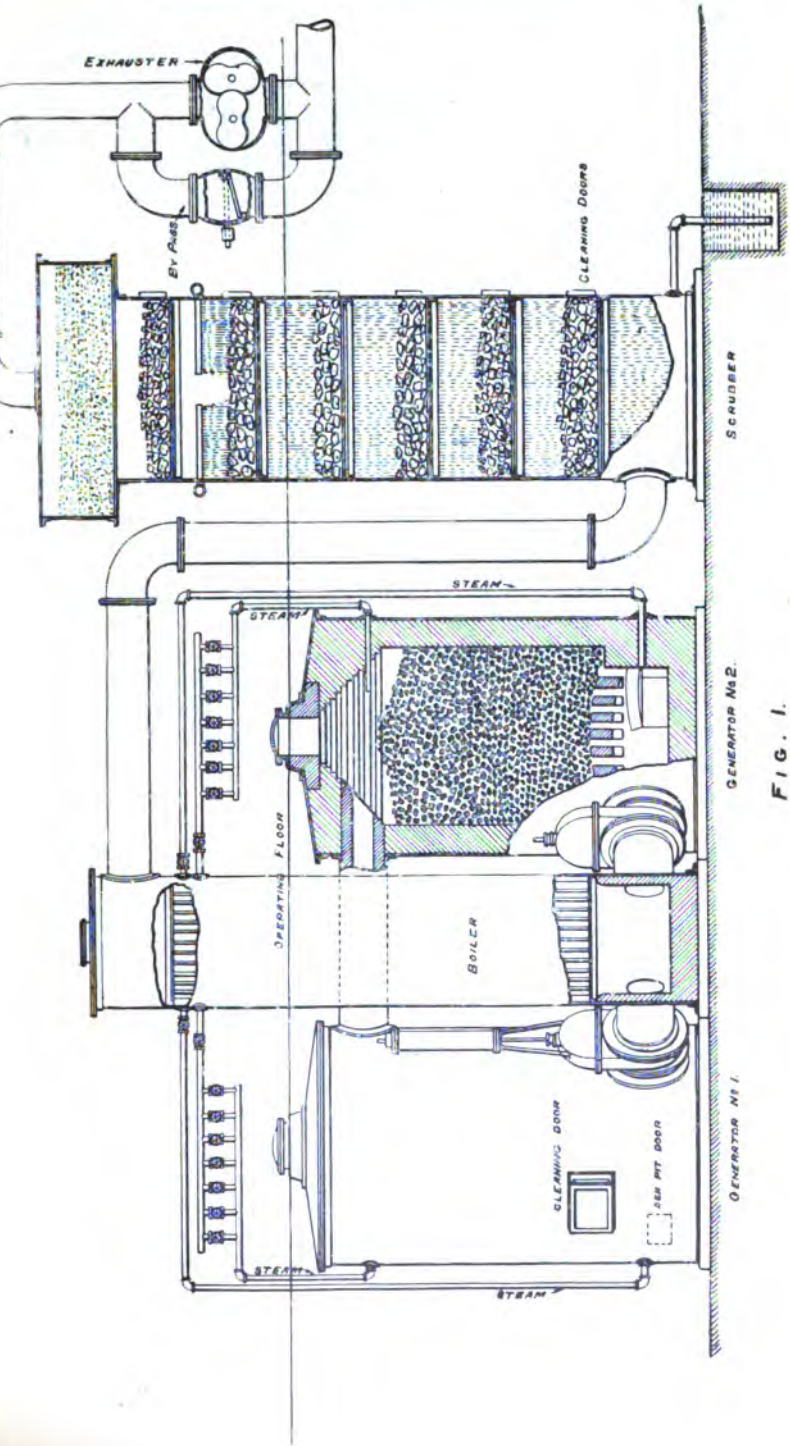
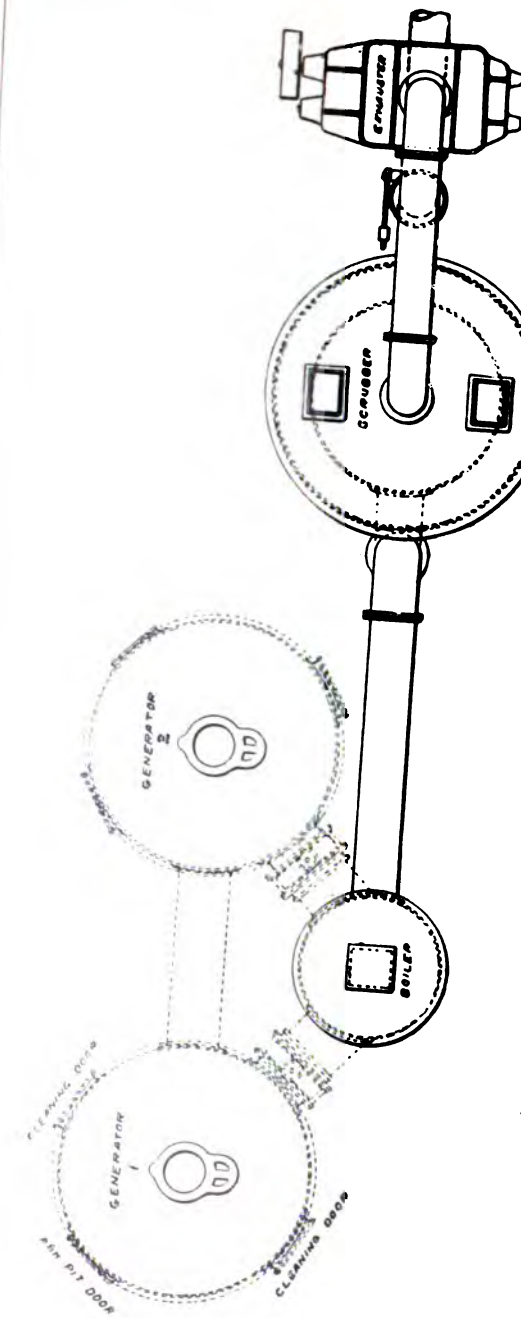

EXHAUSTER
BY PASS
CLEANING DOORS
SCRUBBER
STEAM
STEAM
OPERATING FLOOR
BOILER
GENERATOR No 2.
GENERATOR No 1.
CLEANING DOOR
ASH PIT DOOR
STEAM
STEAM

FIG. 1.


ENGINE
SCRUBBER
GENERATOR 2
BOILER
CLEANING DOOR
GENERATOR 1
ASH PIT DOOR
CLEANING DOOR

large proportion of their heat for the production of steam to be used under generators for decomposition.

The great advantage of the double generators is that as all the gas is made to pass through the fire, the tarry matter from the coal is converted into fixed gases that can be conducted any distance through ordinary pipes, and at any temperature or pressure.

In operation, a plant, such as I have described, will produce about three volumes of producer gas to one of water gas. The production per ton of bituminous coal is about 35,000 to 45,000 cubic feet of water gas, and 100,000 to 150,000 cubic feet of producer gas.

This system is, however, more especially adapted to large power plants, and, except under special conditions, is of greater capacity than is required for small units.

Semi-Water Gas.—In order to produce a cheap apparatus for small plants, extensive experiments have been made, resulting in what is known as the semi-water gas producer. Since then a large number of different makes have been placed on the market, in sizes from 8 horse power and upwards. This is an evolution of the water gas apparatus, i.e., in the water gas plant, steam and air are supplied alternately, whereas in the semi-water plant, the steam and air are supplied at the same time, and the amount of steam so reduced in volume as not to interfere with the temperature of the fuel (usually about one pound of steam per pound of fuel consumed). The general form of apparatus comprises the following principle parts, viz.:—

1.—The producer, or generator.
2.—The saturator.
3.—The hydraulic box.
4.—The coke scrubber.

Producer.—The producer is a cylindrical steel shell lined with firebrick and fitted with a revolving grate. There is an annular space between the brickwork and the outer shell, through which the air for the combustion of the fuel passes from the saturator to the bottom of the producer. A central collecting bell is suspended from the top and keeps the fuel at a uniform level. One or two charging hoppers are provided, either in the centre or one on each side of the bell. The bottom of the producer is closed by a water seal, which permits of cleaning and removal of ashes without interruping the continuous operation of the plant. The air and steam, in passing upward through the incandescent fuel combines with the carbon in the formation of gas.

Saturator.—The saturator is a water jacketed pipe or vessel in which water is maintained at a constant level. The gas, as it

passes from the producer, is hot; the saturator not
the temperature, but the entering air in its passage
saturator on its way to the bottom of the produc
contact with the heated water, and picks up a cert
steam vapour, which on its course through the fire
calorific value of the gas there being formed.

In some cases the separate saturator is dispense
evaporator attached to the top of the producer whic
necessary steam.

Hydraulic Box.—From the saturator the gas
hydraulic box, which acts as a seal and prevents the
ing up into the producer. It is provided with an
trough which permits the removal of accumulated
then enteres the coke scrubber.

Coke Scrubber.—This is a cylindrical steel shell fi
through which a small quantity of water trickles. T
cleaned of any tarry products it may contain, and is
mospheric temperature, and finally, before reaching
the gas passes through the sawdust scrubber.

Sawdust Scrubber.—This is fitted with trays filled
or other similar material which exposes the gas to
surface, and removes the last vestige of fine ash
matter which may have been carried over.

Under some circumstances the sawdust scrubber
sary, the gas being sufficiently clean after leavi
scrubber for engine use.

Starting.—To start the plant a small hand blow
fire is started in the generator, and coal added. Th
valve is opened, and the blower used until the fuel b
descent, and in a condition to give off gas (which
from 10 to 15 minutes) when the atmospheric valve
the gas allowed to pass through the apparatus. The
started, and the production of the gas becomes auton
tion stroke of the engine furnishes the draft throug
draws sufficient air and steam to combine with the c
up the supply of gas.

Fuel.—the fuel most suitable for consumption
water gas producer is anthracite, owing to its freed
phur, smoke and other impurities, and the product of
is about 160,000 cubic feet of gas.

Of the different kinds of gas here mentioned, th
gas is by far the richest, or highest in heat units, co
600 heat units per cubic foot.

The second in point of calorific value is the wate
ing about 300 heat units per cubic foot.

The third is semi-water gas, containing about 150 heat units per ic foot.

And the lowest in calorific value is the producer gas, contain- about 110 heat units per cubic foot. This latter is due to the t that the gas is obtained by a combination of oxygen and car-, but to get the required volume of oxygen, we have to intro- e four times the volume of nitrogen (as air is composed of one- oxygen and four-fifths nitrogen) thereby producing a very ak or lean gas, as nitrogen has no value in heat energy.

The principle upon which the producer operates is, that limit- the amount of air or oxygen admitted to the fuel to one half at would be required for complete combustion, or 1.33 pounds pound of carbon, carbonic oxide gas is formed instead of car- ic acid gas (the latter being a product of complete combustion). the steam passing through the incandescent bed of fuel is dis- egrated, the oxygen combining with the carbon and the hydro- remaining in the gas, very much improves its quality; owing its high heat value and the quantity of air necessary being re- ced and to the oxygen obtained from the disintegration of the am, the nitrogen is reduced in like ratio.

In semi-water gas the heat value is increased to about 150 .U. per cubic foot, and in straight water gas about 300 B.T.U. cubic foot.

Illuminating gas, owing to its being made in air-tight retorts, almost entirely free from nitrogen.

The following table gives an approximate percentage of the incipal constituents of the four different kinds of gas:—

	Illuminating.	Water.	Semi-Water	Producer.
Carbonic oxide..	5.7	42	25	23
Hydrogen..	46.5	48	19	2
Carbonic acid	3.1	6	6	3.6
Nitrogen.	3.7	5	49	63.5
Marsh Gas	35.7			7.4
Heat units, approx.	600	300	150	110

Relative power developed with various qualities of gas is own in diagram, Fig. 4, in which semi-water gas at 150 B.T.U is ken as standard.

Producer gas of	110	B.T.U.	= 90 H.P.
Semi-water gas of	150	"	=100 H.P.
Water gas of..	300	"	=112 H.P.
Coal gas of	600	"	=117 H.P.

RELATIVE COST OF POWER.

In making a comparison of the costs of the various motive wers, to simplify the matter we will consider the question of

fuel only, except in the case of illuminating gas, only consider at its cost ($1.00) per 1,000 cubic feet

Gasoline.—The consumption of gasoline in a is one-eighth of a gallon per B.H.P. hour. This at 2 lon will figure out as follows:—

.125 x 10 x 312 = 390 gallons @ 20 cents = $ per annum.

Illuminating Gas with the Modern Gas Engine.—I produced with from 14 to 16 cubic feet of illumina average of 15 feet per hour. This would figure out

15 x 10 (hours per day) = 150 x 312 (days per cubic feet @ $1.00 = $46.80 per annum per B.H.P.

Steam.—The average automatic high pressure powers requires from four to eight pounds of coal B.H.P., take the average six pounds; this figures o

6 x 10 (hours per day) x 312 = 18,720 lbs. @ $37.44 per B.H.P. per annum.

Semi-Water Gas from Anthracite Coal.—The mos engine builders will guarantee their engines to de on one pound of coal in the generator; this will fig lows:—

1 x 10 x 312 = 3,120 lbs. of coal, $5.00 per to B.H.P. per annum.

Semi-Water Gas, from Gas Coke.—The author h tained a copy of a test of an electric power plant o The fuel was common gas coke and the consumpti per hour per B.H.P.; this figures out as follows:—

.92 x 10 x 312 = 2,870 lbs. of coke @ $4.00 = $ per annum.

Water Gas.—With large gas plants of 500 H.P. Crossley Bros. can produce a B.H.P. on .80 lb. of per B.H.P.; this would figure out as follows:—

.80 x 10 x 312 = 2,870 lbs. of bituminous coal @ per B.H.P. per annum.

Summary.

COST OF POWER FROM VARIOUS MOTIVES PER B.H.

Power from gasoline..	
" " illuminating gas	
" " steam engine..	
" " semi-water gas..	
(anthracite coal)	
" " semi-water gas....	
(common gas coke)	
" " water and producer gas..	
(bituminous coal)	

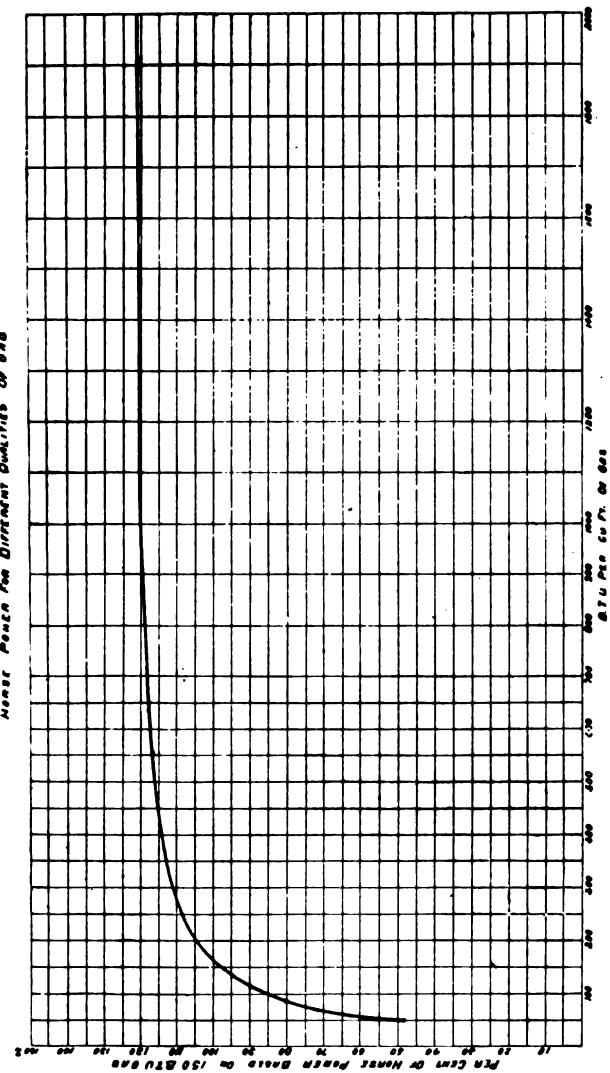

Horse Power for Different Qualities of Gas
B.T.U. Per Cu. Ft. of Gas
Per Cent of Horse Power Basis on 150 B.T.U. Gas

Fig. 4.

From the foregoing it will be seen that the suitable gas producer will generate power at a than any other source of power, although it is c few years that it has been brought to its pres Increased sizes and higher compressions are features in its recent development. These chan tated material modifications of design.

Strains, due to increased heat, and higher operation of the large valves and the older sibility, therefore, new devices were necessary new requirements.

Figures 6, letters A., B. and C. show the cy engines as now made by Crossley Bros., showin the mode of constructing the main casting, wat valve and cylinders. From these it will be see valve box is now a separate casting, thus rem main causes of fractured breech ends, which w causes of trouble with large engines. There is the hot working fluids which has not got water with the exception of the head of the inlet val cool by the admission of each fresh charge. Th factory method of preventing pre-ignition, whi liable to occur with gases of high calorific va large percentage of hydrogen, such as illumina and semi-water gas.

"The use of large engines for driving direct for various purposes is rapidly coming into pr continent and in the United States. In some c special purposes, large engines are running nig full output; this, of course, means a most sever of the engine; a year's run on such duty bein three years' ordinary work, and in one case an ran seven months continuously without being are a number of instances of large engines ru total hours of the year, the 3% including sto causes, either affecting the engine or the el combination."

"The requirements of the electricians for st and accurate governing, have now got far beyo pated some years ago."

For great accuracy in the governing of lar "Otto," or four stroke type, it is desirable to u any suitable combination, and an impulse aut by the governor; such an engine, if properly c almost perfect regulation. In two engines tes

K

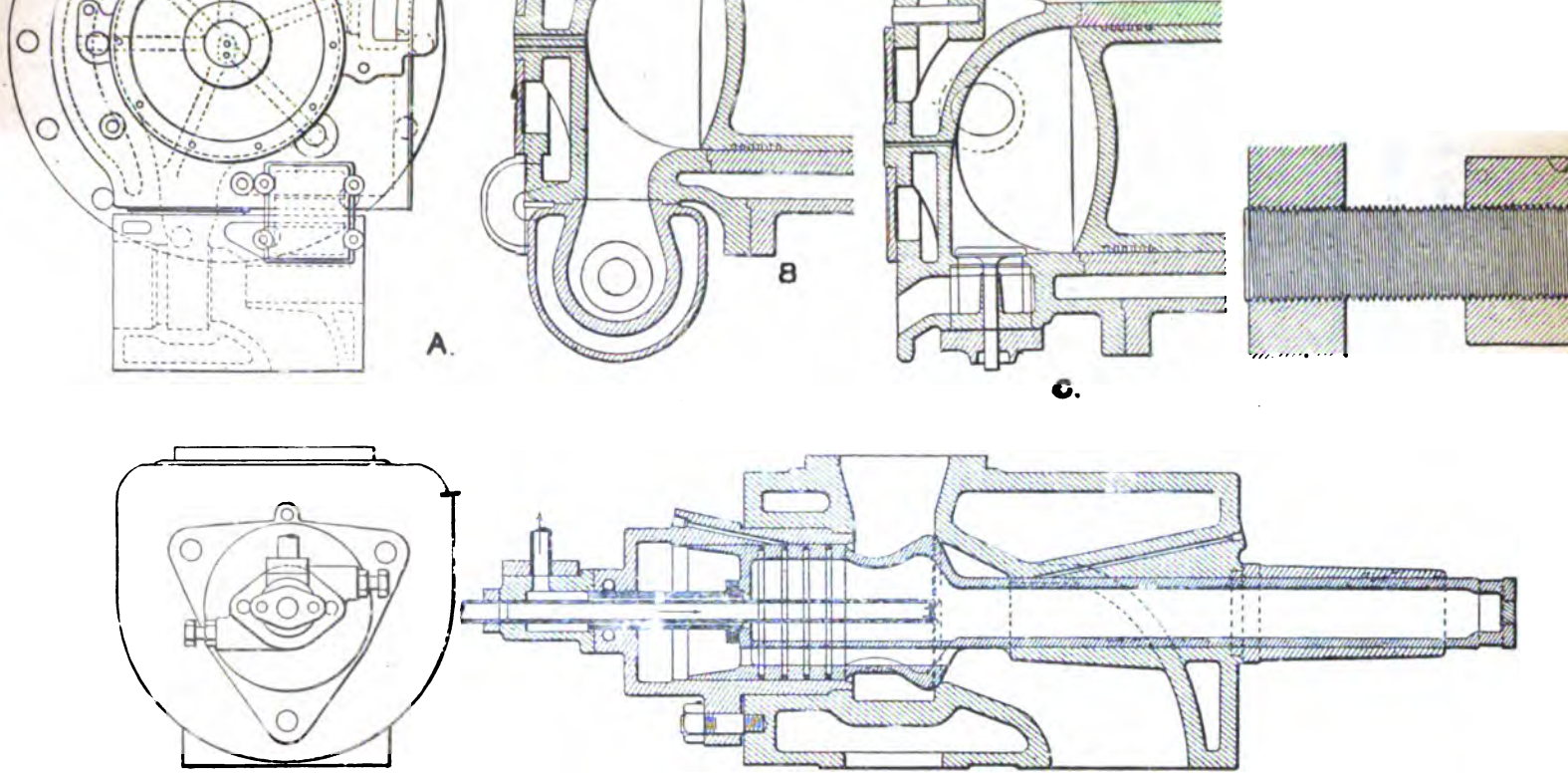


Fig. 6.

Atkinson, M.I.C.E., the variation between ful
was three-fourths of one per cent.

Ignition.—The hot tube ignition has prov
tory, and when suitable gas is available, it is
on it for stationary engines. Hot metal tub
most entirely disappeared, and long life porcel
place.

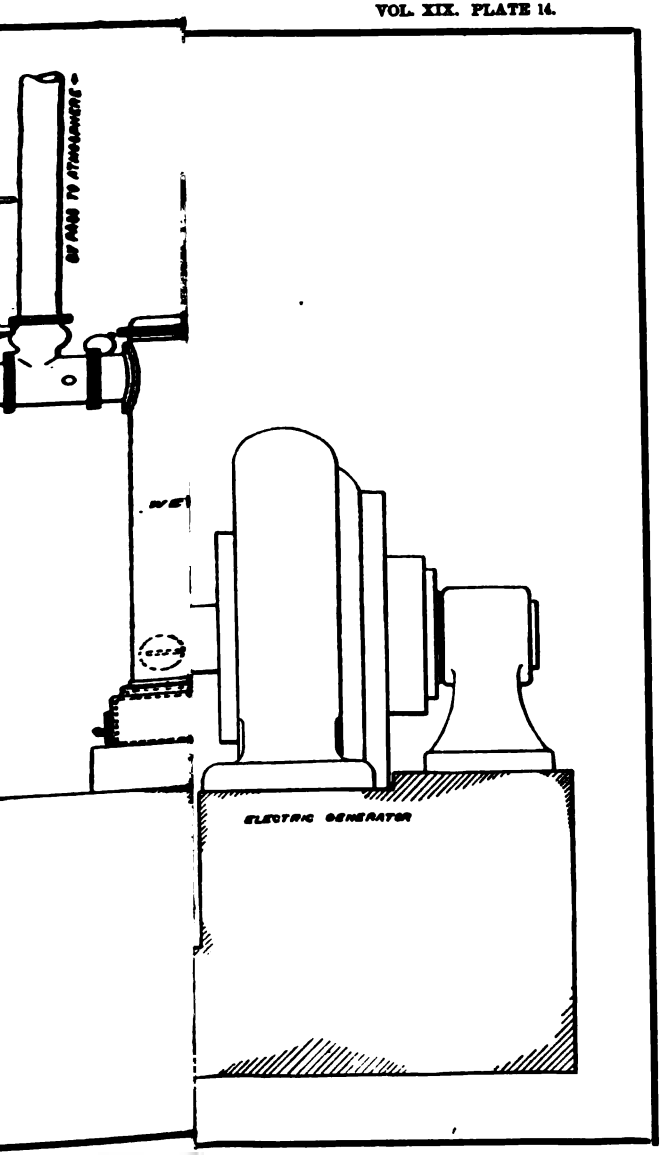
"When two tubes are fitted to an engin
chimney and flame, its own separate ignition
means of shutting off either to replace a bur
ping, it looks as if there were not much roor
this direction."

There are numerous instances when a s
not available, and electric ignition has to be
pose, unless a constant supply of electricity i
dynamo machines are considered the best.

For the lighting of large dwellings, or o
there is no power used for other purposes, th
for operating an electric generator is not onl
expenses than the steam engine, but the co
for the lighting of towns and villages at the
consumers; but when the generation of produ
for such use on the premises of the electric pl
persons who operate the electric plant, the sav
lighting is several fold less than by direct g

When the mere fact of the cost of gas fo
its cost for producing the same light by its u
run an electric generator is considered, the d
electric lighting in preference to direct g
apparent.

It has been known for some years that for
about one-half the volume of gas consumed i
produce the same amount of candle power
engine for generating electricity for lighting.


BY PASS TO ATMOSPHERE
ELECTRIC GENERATOR

DISCUSSION.

hcroft asked as to the relative cost of steam and gas stallation. It appeared to him that Mr Laurie compared of gas in one case with the cost of the engine in the Mr. Ashcroft.

aurie replied that in the case of the ordinary steam plant, ngine would figure 30 to 35% higher, but if the latest im- ts were adopted for a steam plant, the cost would be about It was very difficult to make close comparisons, as con- ere so varied. Mr. Laurie.

Henry Goldmark asked what disposition had been made of cer gas in this comparison with water gas. Mr. Goldmark.

aurie replied that the water gas was taken in the abstract. ucer gas would not figure out more than 100 to 110. Some- in this case, the two were mixed in one gasometer. Mr. Laurie.

t. J. Durley said that at the end of the paper the author re- the method of ignition used in modern gas engines, and on the whole, hot tube ignition had been found to be the sfactory. That was not altogether in accordance with his ce, and he wished to ask Mr. Laurie whether it was not a in many large engines which were being built at the pre- e, electric ignition had been found very satisfactory. His ce, so far as it went, had been that electric ignition was isfactory from one point of view, inasmuch as weak mix- ld be ignited very readily. There was likely to be trouble tube ignition when weak mixtures were encountered. The ich Mr. Laurie had given were fuel costs only, and would some modification, taking into account labor, etc., and all r charges which had to be met. He also wished to ask these figures were not for test runs. He would like to empha- difference between figures which could be obtained for a lant or a gas engine, for a run of a week or ten days, and res for permanent running. He did not want to minimize omy of gas engines, but he did not think it was quite so would appear from the figures which were based on short e gas engines had one considerable advantage. In the case of standing ready for use, the stand-by losses were not nearly as in the case of the steam plant. Another advantage he gas plant undoubtedly had over the steam plant, unless er was fitted with all the latest type of equipment, was that Mr. Durley.

Mr. Durley. it had not so great a load factor. In in an installation of considerable size, tion of anthracite coal on a run of con 2.2 lbs. per K. W. hour, the cost of fuel tor was approximately 25%. There w which could make so good a showing. points in connection with the economy Laurie had not had space to show. On of economy in the production of the ste purposes. Of course, in most cases a s were employed, but now efforts were bel gases to generate the steam required by no reason why this should not be done, was ample for the purpose, and in large saving might be effected in that way. which existed in England, was the by-p ketable value which reduced very mate sumption. He would like to hear whet session of any figures which would bea

Mr. Laurie. Mr. Laurie replied that in the mode some of the plants were arranged to m but in the case of small plants which purposes, it would make it much more In reference to the boiler for steam produ mentioned that the waste heat from the required. There would be no fuel req course the boilers were only used for the for small producer plants there was no reference to ignition, where producer ga inating gas was to be had, electrical ign so far as the hot tube ignition was conc the largest concerns in the Old Country

Mr. Goldmark. Mr. Henry Goldmark said he did no ledge on the subject under discussion, b tion of using gas in connection with Angus shops a good many boilers wer heat the buildings, and this finally indu gas for use in prime movers. But a utilize gas engines instead of steam eng again in connection with the furnaces i were many furnaces which could be o oil, and a number of propositions we turers of gas apparatus. The idea wa

like the one outlined here, by which water gases would be ied for the furnaces, and at the same time there would be set a considerable quantity of producer gases which would not be in the furnaces, but which could be used in gas engines. The llation of gas engines as an auxiliary to the steam engines, to care of the peaks, was therefore considered. Mr. McHenry, at time chief engineer, was very much interested, and went the matter very thoroughly. It was ultimately decided not opt gas, as the first cost of apparatus proved to be very and it was seen that under the conditions it would be more economical to take the gas and burn it r the boilers than to install gas engines. Of course it was zed that the gas would be much more efficient in the engines under the boilers, but cost considered, it was very much bet- o use the gas under the boilers. The total cost of the plant d, however, have been very great—in fact, over $200,000—simply rovide gas for the blacksmith purposes, so that oil furnaces ultimately adopted, which, according to Mr. Toltz, gave better ts, taking everything into consideration. Mr. Goldmark.

r. E. G. M. Cape remarked that the figures which Mr. Laurie had n of the comparative costs per h.p. per annum, were very in- ting, but perhaps discriminated somewhat in favor of gas ts. In his item for steam power, Mr. Laurie had taken an age coal consumption of 6 lbs per h.p. per hour. With an oration of 8 lbs. of water per lb. of coal, this would be the e thing as requiring 48 lbs. of steam per h.p. per hour. Of se in a steam power plant of any size, a much better result than would be expected. With compound engines worked under 200 pressume and 15 degrees super-heat, and a vacuum of 28″, it possible to develop one horse power per hour, with, say 14 lbs. team. Mr. Cape.

A great thing to be said in favor of steam power in a country Canada was that large quantities of steam were required in the nary plant for heating purposes, and this steam, which had to produced for seven months of the year, no matter what the er requirements might be, could be used in the steam engines be- being put into the heating system; in this way the steam was d twice. Thus either heat costs nothing, or power costs nothing ing the winter months.

In heating factories or shops, it was often found that the steam uirements for power very nearly balanced with the requirements heating. This was the case in a plant which we had in mind, ere turbines are used to supply the power. The guaranteed con- nption per K.W. hour of these machines was 43.8 lbs. of steam

Mr. Cape. non-condensing, and 19.8 lbs. with twenty-eigh the steam in both cases being supplied with and 150° Fahrenheit super-heat. The plant w one or both of the turbines could run either co ing direct into the heating system.

Mr. Laurie. Mr. W. H. Laurie answered that in referenc tion, he had referred in the comparison to smal test of a high pressure steam engine 20" cylinde 3½ lbs. per indicated h.p. Indicated h.p. and b different. The estimated average brake h.p. w a very fair figure since not half the engines in t at 8 lbs. That was for small power, from 5 to refer to high power engines and large plants improvements, because they were not used in t

Mr. Ashcroft. Mr. G. B. Ashcroft said he knew of one gas had been in operation in Montreal for somethi was a 25 H.P. plant, gas producer, using anthra was using it for power, and also had a 6 K.W. g for light. It took about one half of a ma divided fairly evenly between the engine and used city gas and tube ignition, the city gas bei In the morning, when it was started up, city ga producer was in working order. In the winter to its full capacity. It used about 250 lbs. of cally 1 lb. per H.P. Figuring 10% for interes would bring the power to $31.30 per H.P. per an been in operation for more than a year.

Mr. Durley. Mr. R. J. Durley remarked that the figures much information, since the load was not know mated that the plant ran ten hours per day, but the H.P. was not stated. Unless there w regarding the load factor, the cost was perhaps

Mr. Doyle. Mr. S. G. Doyle, introduced by Mr. Ashcro discussion. He said that in his opinion, gas pow gas engines and gas plants supplied by the best turers, was, next to water power, the cheapes existence. Some engineers doubted whether t be relied upon to give its rated power continu various fluctuations of load such as were expe age central station. This question was very ab Hugh Campbell, M. Inst. M. E., in a paper read of the Institution of Electrical Engineers, Lee vember last. Mr. Campbell proved from the

nes in the central stations at Walthamstow, Redditch, North- Mr. Doyle.
, Guernsey and Hebden Bridge, that gas engines could now be
d upon to give results under all working conditions, equal, if
superior to, the results obtained from the best of steam engines,
st in economy they left the steam driven stations far behind.

He quite agreed with Professor Durley that in discussing the
ive economies of gas and steam engines, test or trial runs ex-
ing over a short period only should be ignored. The figures
ing to the works cost to produce power at the Guernsey Elec-
ty Corporation's steam driven central station, and also the
s at their gas driven station, where they have in operation two
pbell gas engines, each of 300 B.H.P., showed a difference in
r of gas engines in some cases of over one cent per unit gener-
These figures included fuel, wages, water, stores, repairs, etc,
were very complete, covering a period of six months of actual
ing.

Another Campbell engine, of 60 B.H.P., operating pumps at the
rworks, Combe-Down, Bath, and carrying an overload almost
he time, was, according to Mr. Owen Bayldon, the engineer in
ge, running on an average 130 hours per week, with a coal con-
ption of only 34 cwt. The steam plant which preceded the gas
nes used from 11 to 13 tons to do the same work.

With regard to the question of ignition, he could hardly agree
Mr. Laurie that the hot tube was the best system. It was a
l system where rich coal gas was available, but even then, if the
rning of the engine affected at all the quality of the mixture,
hot tube was scarcely reliable. Personally, if he were putting
ngines, say for driving alternators in parallel, or for any pur-
where missfires were likely to prove a serious let down, he
ld be inclined to duplicate the igniting apparatus; in the case of
g coal gas by putting both hot tube and electric ignition, and
re producer gas was used, by a double system of electric igni-
.

With regard to the heating question which had been raised in
nection with the application of gas engines in this country, he
ught the seriousness of the heating problem was often over-esti-
ted, and at all events the manufacturer who put in gas power was
rcely worse off than the manufacturer who bought electric power
m a power corporation, and for central station work sufficient
t could easily be obtained from the exhaust gases to keep the
gest of stations up to the required temperature.

Another feature of the application of gas power had been almost
irely overlooked, although it was of no mean importance, namely
entire absence of smoke where gas power was used.

Mr. Doyle. The very latest and best thing that had co the way of gas engines was a 4 cylinder vertical where the balance of the parts had been brough as was possible to get in any moving mass. M manufacturers, claimed that under average worl engine had practically no cyclical variations, a variation in speed between full load and no load out the main switch on the board, was less than variations being almost nil.

GENERAL SECTION.

At the meeting of the section held on Thursday. April 20th, , Mr. Duncan MacPherson in the chair, the following papers e read:—

ER No. 227.

THE CONSTRUCTION OF A TIMBER DRY DOCK.

By G. B. Ashcroft, A. M. Can. Soc. C. E.

Introduction.

Among the pages of the Engineering News for Nov. 28th, 1901, e appeared the following brief note:—"The William Skinner -Building & Dry Dock Co., of Baltimore, Md., formally opened second largest dry-dock in this country on Nov. 25. The dock uilt of timber carried on pile work and the entrance is granite onry backed by concrete. The steel caisson-gate gives an ing 80 ft. wide at the top with 22½ ft. of water over the The general dimensions of the dock are as follows: Length all 628 ft., length on keel blocks, 600 ft., width of entrance at bottom, 60 ft., at top, 80 ft., width of dock on the floor, 62 ft., h at coping, 125 ft., depth of water over sill at low water, ft."

The same journal in its issue of Jan. 9th, 1901 devoted one e to a more extended notice of this work.

In the present paper it is proposed to give a more detailed unt of this dock as it actually is; the methods of construction loyed; the contract prices, quantities of material and cost ; a comparison of this with the other large docks to be found g the eastern coast of North America; and in conclusion, to w what three years of operation has done to verify the judg- t of the designers and builders in their solution of the various ineering problems which were presented to them.

General Description.

The ship-building plant of the Wm. Skinner & Sons Co., is ted at the foot of East Cross St., in Baltimore, Md. At the

time of building the new dry dock, this plant
work shops equipped with compressed air mach
railway for the docking of small vessels.

The port of Baltimore could boast of seve
in addition a timber dry-dock of small size, c
years ago and at this time in a bad state of re

The size and tonnage of the larger vessels
had long since exceeded the limits of its doc
whenever repairs were needed upon such shi
pelled to seek the larger docks at Newport New

The "William Skinner & Sons Ship-Buildin
of Baltimore Md.," was organized. The newly
then secured additional property adjoining th
pany, and had plans prepared for a modern
large dimensions. The proposed site of the ne
by old brick warehouses and an old pier. It
secure sufficient property so that the propos
constructed within the then existing shore line
fore necessary to plan for building the entra
ft., of the dock body, in the open waters of the h
rise and fall of the tides at this point is abou
the maximum has been known to greatly e
when both tide and wind are favorable for
The water is brackish.

Borings were made to ascertain the probal
foundations, and soundings taken in the harb
plans and specifications were prepared by Mess
Consulting Engineers of Cleveland, O. As final
plans called for a dock body built of timber, s
an entrance composed of concrete faced with g
a steel caisson gate.

The work was divided into four parts as
of contracts as follows: 1st. Dredging and
structures and piers. 2nd. Construction of t
heads and cofferdam. 3rd. Construction of
masonry of the entrance and power house
Construction of the timber work and the main

A contract was signed on June 30th, 1899,
Construction Co., of Wilmington, Del., coverin
parts 1 to 4, and they commenced operations
The mechanical equipment, the caisson gate
ture of the power house were arranged for by
be noted later.

Detailed Description.

Foundations.

The nature of the soil upon which the dock was built varied nsiderably, as shown by the materials encountered during nstruction. In excavating one of the bulkheads, after the river id had been removed, there followed a layer of yellow clay some or 10 inches in thickness; a few inches of vegetable matter embling peat; a stratum 4 feet thick, composed of coarse artzite pebbles and fine red sand merging into densely compacted ers of pure sand; and beneath all extending to some undeter-ned depth, a pure white clay. Before water had reached it, s clay was exceedingly hard, would take on some polish when bed, and was sometimes used by the carpenters to chalk lines. er standing some time in contact with water it became softer, embling somewhat the texture of castile soap.

The concrete work about the dock entrance was in all cases ced directly upon this clay. It is doubtful if any of the piles sheet piles ever penetrated this material to any extent. In t those of the temporary work which were afterward pulled, peared as if they had landed upon a rock, and the whiteness of ir points was evidence enough as to what they had landed on. No actual rock was however, encountered at any point.

Protection Work.

The safety and efficiency of a timber dry dock depends in a ge measure upon the possibility of keeping water away from piles and foundations. In the work under consideration this s a very important matter, for as has been mentioned above, er 200 feet of the structure was situated in the waters of the bor.

It was proposed to surround the entire dock, (excepting of rse the entrance way) with a single line of sheet piling. mmencing back some 65 feet from the shore line and extending ward to the limits of the dock, this line was to be doubled, the lines being spaced 16 ft., apart. Round piles of yellow pine re driven every ten ft. upon the outer sides of these were drift-ted two parallel lines of 12 by 12 inch Southern pine waling ips. One strip being placed at the level of the bulkhead top, l the other below low water line. The lower waling strip was itted from the sheet piling within the shore lines.

Timber braces, 12 by 12 inch Southern pine were placed across s bulkhead at every pair of the guide piles and a 1¾ inch iron

tie-rod beside each brace. The piles were sligh
the braces in position.

Along these guide wales was driven a c
Southern pine sheet piles, tongue and grooved,
in length. The sheet piles were 10 by 12 inches
tongue 4 inches square. Each pile was secu
strips by ⅞ inch machine bolts.

Between the outer ends of these perma
temporary one of like character was driven,
cofferdam, and two single lines of temporary
driven from bulkhead to bulkhead, enclosing th
to be excavated for the entrance foundations, a

Entrance.

The entrance proper of the dock, is concre
backing, faced with heavy granite masonry. T
12 feet wide, the middle apron 12, and the inner
of each is level with the exception of the inne
tance of 12 feet slopes downward to the cross
body of the dock.

The entire surface is bush-hammered to a s
sills, two in number, rise vertically from the
18 inches. The minimum width of entrance at t
sill is 60 ft.

The granite abutments are rock faced, wit
the bush-hammered jambs. They rise vertical
sill level a height of 29 feet and recede 10, thus
of entrance at the coping level, 80 feet.

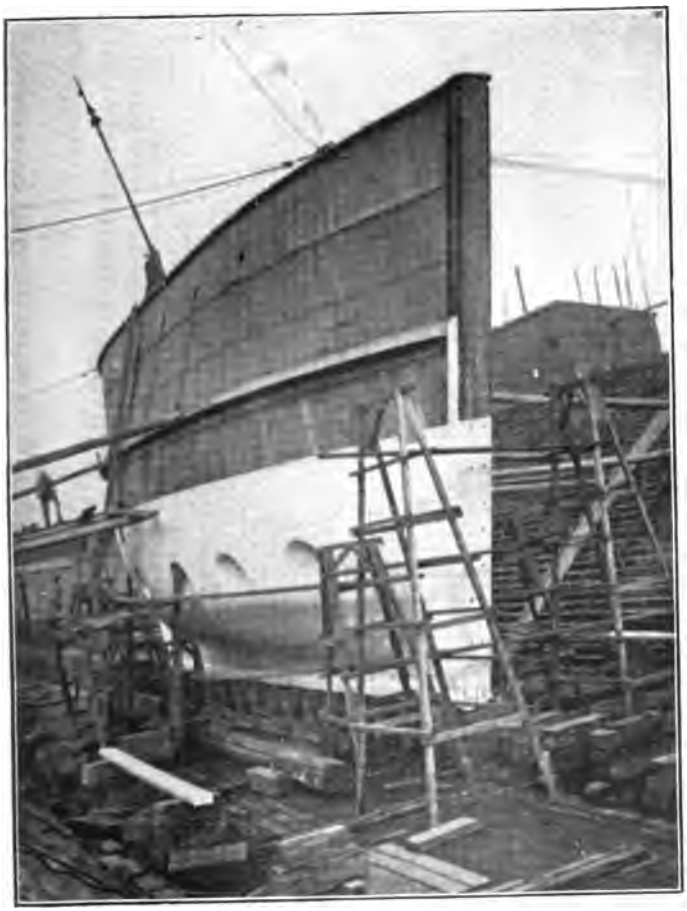
Each stone in course is doweled to the s
two iron pins, each 1 inch square and 4 inches

Beneath the aprons are 11 steel bands, 10
feet, bent upward at the ends, which serve to b
together.

Behind the north abutment, the concrete ba
a solid mass to the protection bulkhead, and in
ing behind the south abutment, are formed th
engine pit, and drainage tunnel from the main

Gate.

When the dock is in use the entrance is
caisson gate whose general dimensions and cons
upon the drawings accompanying this paper a
graphs here shown.



THE CAISSON-GATE (COMPLETED).

The material specified was medium, open hearth, acid steel, esting from 54 to 62,000 pounds in tension, per sq. in., and ontaining not more than .08% of phosphorus and not more than 4% of sulphur.

A 4″ by 12″ oak strip is fastened along each face of the keel, em and stern posts, to which is attached a 10″ by ½″ gum gasket. carries a permanent ballast of concrete.

For filling the dock, it is provided with six 36″ valves, and for ater ballast, four 6″ valves and one 8″ centrifugal pump with eam engine. Steam is supplied from the boilers in the main wer house.

The gate draws 13′-8″ of water when carrying only permanent llast, and at such times its displacement is 212 tons. It was ilt under special contract, by the Spedden Ship Building Co., Baltimore.

Main Body of the Dock.

The bottom of the dock is supported by 13 longitudinal rows 20 ft., piles. The five center rows are spaced 4 ft. c. to c. longidinally and 3 ft., c. to c. transversely. Upon these comes more rectly the weight upon the keel blocks. The other 8 rows are aced 8 ft., c. to c. longitudinally and transversely as shown on e "Half Midship Section" on the drawings. The sides of the ck are supported by rows of 25, 30, 35 and 40 ft., piles, spaced and 8 ft., on centers. The piles are capped by 12″ by 12″ yellow ne timbers, secured to each pile with 1″ by 20″ drift bolts. The ain cross timbers are spaced 8 ft., c. to c. They consist of Oregon Douglas) Fir, 16″ by 18″ by 70′ in length. Midway between each these on the center line of the dock, is a similar piece, 14 ft., length. They are secured to the pile capping with 1″ by 30″ ift bolts. Along the sides of the cross timbers are spiked 4″ by ″ floor joists, and from the ends of the 14 ft. cross timbers, 6″ 10″ floor joists extend to the foot of the side slopes. Upon ese is spiked a flooring of 4″ white oak plank. The first 80 feet dock floor adjacent to the entrance and the last 40 next the ad, is on a level with the tops of the cross timbers. The balance 4″ below the level at the center line and slopes uniformly toward e sides, on a grade of 3″ in 30 ft. The floor rises toward the ead of the dock on a grade of 6″ per hundred feet. The slope mbers are spaced 4 ft., c. to c., being alternately 12″ by 14″ and by 14″ yellow pine timber. They are framed into the cross mbers at the bottom of the slopes, and secured to the slope pile pping by ⅞″ machine bolts. The yellow pine altars were cut om a timber 10″ by 14″, so that when placed in position they ould have a rise and tread of ten inches.

They are secured to the slope timbers by
and abutting ends are doweled with 1 inch b
They are laid with the treads horizontal, whic
course to disappear about every 170 feet, owin
dock floor.

Four chutes are provided on each side
material. At these points the altars are omit
plank spiked upon the slope timbers.

Across the ends of the long floor timbers
in the slope rows are placed 6 by 12 inch yellow
bolted to the piles with ⅞ inch machine bo
waling strips are placed 12 by 12 inch braces, n
line of bracing from the outer row of piles to th
Another 12 by 12 inch brace extends from the
row of piles to the capping of the third row,
tie rod is placed beside it. This combination
forms a truss as shown on the drawing.

The head of the dock was originally desig
the sides, that is approximately, a 45 degree slo
tion, however, an extension was built into th
box with vertical sides, thus gaining over 24
length.

Drainage System.

From the masonry of the entrance to the
the floor rises uniformly 6 inches per 100 feet
line to the foot of the side slopes the floor falls
in 30 feet. This causes the water to flow to
entrance of the dock. Along each side the
floor length, extends a drain some 5 feet wi
built of 3 inch plank spiked to the piling as
drawings.

The oak flooring covers this drain but is n
the pieces are not fitted so closely together.

Adjacent to the masonry is a 6 foot cross d
side drains empty. The plains show this to be
construction, but as actually constructed, the
masonry aprons were extended into the bod
enough to build this cross drain in concrete.

From the cross drain, a 6 foot square tu
concrete foundations, runs beneath the south
to the pump well below the engine pit.

This pump well is 23 feet 9 inches long by
roof is composed of a layer of concrete 10 feet

SHEWING CONDITION OF SLOPE PILES, DRIVEN BEFORE
OUT. THE SIDES SLID INTO THE DOCK BOTTOM
MANY OF THE PILES WITH THEM

SHEWING FORM OF TRAVELLER USED FOR HANDLING

SHEWING THE SIDE SLOPE TIMBERING.

SHEWING FEET OF PILES, DRIVEN FROM TEMPORARY BRACING, BEFORE EXCAVATION HAD BEEN COMPLETED TO POINT OF CUT OFF.

centre is a 6 foot square pier to which run 12 inch I-beams n the side walls, as a support to the concrete roof and the hinery. Into this well extend the suction pipes from the rifugal pumps.

Mechanical Equipment.

For the emptying of the dock there are provided three 36 , double suction, centrifugal pumps, directly connected to ple, vertical, non-condensing engines. To take care of the age during use, an additional centrifugal pump, with 12 inch harge, is connected to a small vertical simple engine. This hinery is located in a "pit" formed in the concrete which s up the south abutment. The floor of this pit is 22 feet w the level of the top of the dock, or 15 feet 6 inches below n low water line. From each of the large pumps, two 28 inch ion pipes pass vertically downward through the 10 feet 6 es of concrete into the pump well below. There is one 42 , horizontal discharge pipe for each pump.

Steam is supplied from the boiler house at 125 lbs pressure. ee 350 H.P. Heine Safety Water Tube boilers, an auxiliary ical boiler, two fire pumps, and fan and engine for forcing draft, complete the equipment of the boiler house.

On actual test after completion, the average efficiency of each n pump was 38,250 gallons per minute. The indicated horse- er of the engines varied from 185 at starting to about 300 at finish, giving an average efficiency for the pumps of 58%. The imum efficiency noted at any time during the test was 72½%. se pumps and engines were built and installed by the Morris hine Works of Baldwinsville, N.Y.

Construction.

General Scheme.

Broadly speaking the proposed plan of operation was as ows: After clearing off the existing structures and old wharves, dredge away the material to the approximate lines of the dock tom and side slopes; to drive the permanent protection work ile this dredging was in progress; to drive the temporary erdam across the ends of the bulkheads, immediately the dging was completed; to pump out the water and mud from the in thus enclosed; to drive a line of 20′ permanent sheet piles ng the outer and inner face of the aprons; to further excavate hin this box to the white clay stratum and upon it start the crete foundations for the masonry; to build the masonry tments, pump well, engine pit, powerhouse and main body of dock.

This plan was modified considerably as v
description to follow.

Contracts were signed in June 1899, and
to work almost immediately. By the followi
site had been cleared and dredged out to the
the permanent protection work finished, excep
the head of the dock which was never comp
noted later when we come to consider the cha
original plans, when constructing the head o

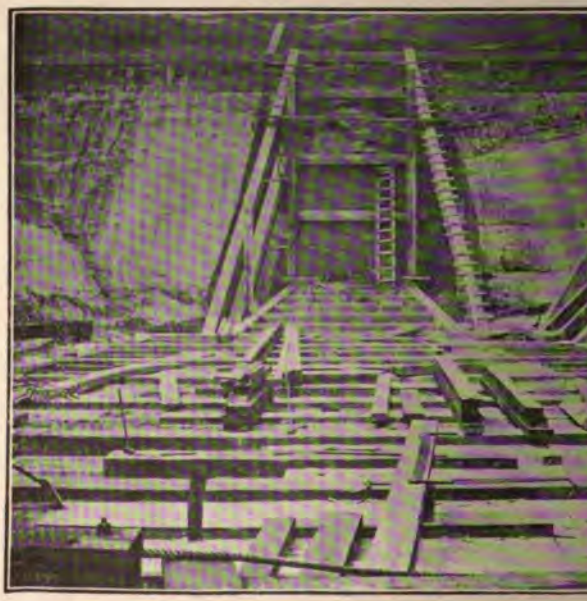
The temporary cofferdam was driven into
was then ready for pumping out. Meanw
machine, mounted upon a scow, had been float
enclosure and driving the outer row of slo
sides of the dock. Why these piles were dr
not quite clear to the writer, unless it was tho
be driven more easily then, than by using a lar
period, or possibly because there was nothing
to do for the time being.

Afterward when the dock basin was pumpe
piles slid into the bottom of the dock, along
or bent so far out of correct line that it wa
them out or saw them off and drive others.
"extra" claims on the part of the Contract
that having once driven them to the lines giv
any necessary redriving should be paid for as
writer's memory serves him correctly, the c
done under protest from the field Inspector,
extras were never entertained.

Pumping out the enclosure began. As the
sank a few feet, those portions of the permaner
ing beyond the original shore line, started
center of the basin, crowding before them th
and the piles which had just been driven.

Pumping was hastily discontinued and the
fill to the level of the water outside. The floa
mentioned above, which had been left inside
piles, upon which were placed the 70 foot Oreg
so as to form a transverse set of bracing fron
head across the dock. This system of bra
shoreward, at 20 foot intervals, as far as any
heads had been noticed or could be expected.
been planned to drive 20 foot sheet piles alo
aprons (as mentioned above), after the dock
pumped out, the water machine drove rows of

SHEWING CONDITION OF WORK AFTER REACHING PERMAN



SHEWING CONDITION OF FOUNDATION AT HEAD OF DOCK,
BE NOTICED THAT THE SOIL STANDS A VERTICA

SHEWING THE BOX PROJECTION IN THE HEAD OF THE DOCK.

IEWING MAIN BODY OF THE DOCK LOOKING FROM THE COFFERDAM.

enting what material was left about the foot of the cofferdam moving into the dock.

Pumping was again started and continued until the bottom e basin was laid bare. A small centrifugal pump and later a ometer, took care of the leakage, which was noticeably greater igh tides.

ENTRANCE.

Excavation.

Within the box like enclosure formed by the bulkheads and two rows of 34 foot sheet piles, excavation was started for the dations of the masonry work and the engine pit. The more erial removed, the greater became the need of temporary ing to keep the sides of this box from collapsing. Complete of bracing were placed in position for every 6 or 8 feet of vated depth and as the 12 by 14 and 8 by 14 inch slope timbers used for this work it was important that they should be cut ttle as possible.

Each set placed made it more difficult to place the next below, l the time came when the long timbers could not be landed in zontal positions and had to be placed wherever a suitable ing could be found.

So thickly were these timbers placed, that at the time the sill stones were lowered into the pit, there was but one ing to be found of size sufficient to admit them.

Excavation was carried to the stratum of hard white clay. In g this it was found that the sheet pile protection had not etrated this clay to any appreciable depth, as in many cases the vation laid bare the points of the piles. More bracing was order of the day, and that immediately.

Leaks at high tide had always necessitated regular pumping, now the water began to find its way down the sides of the et piles and through the gravel stratum at their points, in ntities that became alarming. The original idea of driving a water cut off wall of 20 feet sheet piles along the front and edges of the pit was abandoned, as no pile could be forced this hard layer of white clay. As a substitute measure a ch some 2 ft. wide and 4 ft. deep was dug in the clay parallel the face of and at some distance in front of the outer sill of aprons. This trench was filled with concrete which joined to concrete foundation, formed a stop water as effective as the s would have been.

Concreting was started near the middle of the pit and the ndations raised several feet high. This was extended to within

a few feet of the north bulkhead where th
occured under the feet of the piles. At low
temporarily stopped, by driving inch board
of the piles and dumping dredged material
the bulkhead. Concrete was hurriedly plac
the piles and raised to the same level as th
previously placed. No further leakage of
experienced in this direction. The concrete
the finished level of the lowest masonry co
temporary braces as fast as a sufficient quan
be placed about the bottom of the piles, to
pressure.

Concrete.

The following extracts from the Specific
concrete work are noted. "One part of ceme
and five parts of broken stone, to be throu
hand or suitable machinery, before being pu
enought water to slightly moisten the mass. T
must be accurately measured for each and ev
using suitable rectangular boxes holding not
feet each." "The cement used for concrete
high grade of American Portland, uniform
results by ordinary pat tests in air and in
(especially as to changes in volume), and be
at least 93% will pass through a sieve of 8
and 89% through a sieve of 100 meshes."
slow setting and must not take on an initi
minutes; final set in not less than 3 and
"Briquettes of neat cement must show a min
as follows: Samples kept in air one day and
lbs per sq. in.; samples kept in air one day
575 lbs per sq. in." "Briquettes of 1 part cen
must show a minimum tensile strength as fol
air 1 day and in water 6 days, 150 lbs per
in air 1 day and in water 28 days, 200 lbs
will be taken from each lot of 100 bbls.
Engineer."

"Sand must be clean, coarse and shar
earth matter, and screened or washed if r
used for concrete must be broken into piece
possible, and not more than 2½" in its l
must be kept free from dirt and rubbish
before being used must be drenched with
to be preferred for this material."

SHEWING MAIN BODY OF DOCK LOOKING FROM BOX IN THE HEAD.

SHEWING TEMPORARY BRACING REQUIRED IN FOUNDATION PIT.

The concrete was made in accordance with the specifications, g "Dragon" Portland cement and crushed granite, and was tly machine mixed. The "machine" was of the gravity type, nvention of a local Engineer, who put it on the work as an rimental trial. The result was considered so satisfactory, that believe this machine, or one along similar lines, can now be hased in the open market as a patented invention.

As the accompanying photograph shows, the mixer consists of ght wooden frame work supporting two cone shaped hoppers, vertically above the other, and above these, four pyramidal ers, the combined capacity of which, equalled either of the cones, and at the top, bins for sand and broken stone.

For work in a pit this machine was exceedingly handy. It d be picked up by a dredge boom and placed in any desired tion, and raised as the concrete work reached the lower hopper. In operation it required the services of four men, two to fill four upper hoppers, and a man at each of the others to regulate gates. A scow load of sand and another of broken stone would hauled along side the bulkhead and from this a bucket dredge ld keep the sand and stone bins constantly filled.

The men at the upper hoppers would empty a sack of cement each, and then by opening gates in the bottom of the bins ve, allow the necessary amounts of sand and stone to flow in, ks having been previously made on the sides of the hoppers show the correct proportion of each of the ingredients. The unt of water found by experience to be necessary, would then dashed into the hoppers, and the charges allowed to run into first cone hopper below.

Refilling would begin at the top while the men were caring for first charge in the lower hoppers. The process was thus tinuous, and the product as regards thorough mixing was first s, especially where the mixture was dropped from the lowest per directly into barrows. The capacity of a single charge was roximately 25 cubic feet of concrete, when rammed into place. record for a days run (10 hours) was 110 batches, making ut 35 cents as the labor charge for a cubic yard of concrete in ce.

Masonry.

Upon a seven foot layer of this concrete as a foundation were cted the masonry aprons and abutments.

The stones were massive foliated granite from quarries near rt Deposit Md. The sill stones, 3 and 6 feet thick, were bound ether with steel bands, set on beds of mortar and the joints shed with Portland cement grout.

It required careful work to place these 15 ton blocks with their top surface truly level and their bush hammered faces to an exact transit line.

The course stones of the abutments are doweled on the beds with two iron pins, 1 inch square and 4 inches long. For setting the jamb stones a batter board was used which had been obtained from the ship building company who made the gate. Thus the gate and the recesses in the abutments were built to the same pattern, and there could be little chance of a misfit.

Behind the north abutment as the masonry work progressed the concrete backing was filled in solid to the bulkhead. Behind the south abutment, in the concrete backing, was formed the drainage tunnel from the dock, the pump well, and the engine pit

Tunnel, Pump Well and Engine Pit.

The tunnel from the main dock passes under the corner of the masonry and into the pump well behind the abutment. In cross section it is 6 feet square. At the point of junction with the pump well, a sump pit 6 by 6 feet and 2½ inches deep is constructed in the floor of the tunnel. Into this sump extends the suction pipe from the 12 inch centrifugal pump. It is the lowest point of the drainage system, intended to take care of leakage while the dock is in use. The pump well itself is 6 feet deep and has a floor area of approximately 300 square feet.

In the centre a 6 by 6 foot concrete pedestal serves as a support for the 12 inch I beams which are built into the roof as a support to the weight of the suction pipes, engines and pumps Above the pump well is 10 feet 6 inches of concrete, which forms the foundation of the engine pit. The heavy suction pipes were supported on wooden blocking while the concrete was being placed about them and the blocking left until the completion of the work.

Anchor bolts for the engine bases were about 7 feet long, set within a length of 4 inch gas piping, with heavy cast iron base plates at the bottom.

After the engines had been aligned these gas pipes were run full of cement grout.

There had been plenty of evidence at hand to conclusively demonstrate that a mixture of 1-2-5 concrete was not water proof when subjected to much hydraulic pressure.

As the roof of the pump well would be, at high tide, some 30 feet below the level of the water outside the dock, or subject to a pressure of some 1900 pounds per square foot, it was necessary to provide some means of preventing water leakage into the engine pit. When the concrete above the pump well had reached a point

SHEWING THE 6-FOOT INNER SILL STONES AND MIDDLE APRON.

SHEWING INNER SILL, AND APRON WHICH SLOPES TO CROSS DRAIN.

THE COMPLETED ABUTMENT.

SHEWING PUMP WELL, SUCTION PIPES AND PEDESTAL.

three feet below the finished level of the engine room floor, a 3 inch course of Portland cement mortar (cement 1 part, sand 2 parts) was spread evenly over the surface and extended on all sides a distance of 2 foot 6 inches beyond the finished wall lines of the pit. This 3 inch mortar course was carried up parallel with the walls of the pit to the top of the dock, being back in the concrete 2 feet from the face of the walls. Even with this precaution, the walls appeared to sweat at times, though the moisture did not accumulate in amounts sufficient to run.

This mortar course not having been specified or shown on the original plans became a subject for "extra" charge. It cost in labor and materials a total of $745.00 and the results obtained justified the extra expenidture.

The engine pit is 26 by 42 feet. It is provided at the top with a four foot wide platform, extending around the entire pit, from which stairways lead down to the engines and pumps.

Power House.

The power house is built of brick, set in Rosendale cement mortar. It was constructed under special contract by C. H. Fath & Son of Cleveland, O., for the sum of $5,750.00.

A 13 inch brick wall separates the boiler room from the engine pit, and is continued through the roof. Six, 36 inch steel plate girders, support the roof rafters, which are 2 by 6 inch timbers, spaced 18 inches on centers.

The roof covering is 1¼ inch matched lumber covered with tin. The total floor area figured from the outside dimensions of the stone footing course would be nearly 3274 square ft. which would make the contract cost of the building a little more than $1.75 per square foot of floor area. Figuring the cubic contents from the floor level to the underside of the roof boards, would give approximately 74685 cubic feet, and a contract cost of 7¾ cents per cubic foot.

The writers finds among his notes referring to the power house, that the cubic content of the walls was 7,000 cubic feet, the number of bricks used 116,000, which would give an average of 16½ bricks per cubic. foot.

That portion of power house covering the boilers is located within the lines of the main dock. For the foundations of this and the boilers, piles were driven and covered with a grillage of 10 by 12 inch timbers (old sheet piles removed from temporary work) upon which was placed a layer of concrete 9 feet thick. Air ducts were laid in the concrete for the forced draft.

Sluice Way.

It was originally planned to construct a buried sluice way in the outer end of the south bulkhead, through which the discharge from the pumps should flow into the harbor. The sluice way is shown on the general plan drawing accompanying this paper, but it was never constructed. Instead, the end of the bulkhead was never closed, and the pumps were allowed to discharge into it.

There was some question as to whether the rush of water from the discharge pipes would not scour out the material from around the feet of the sheet piles, and cause the destruction of the bulkhead. But at present writing, the evidence does not show that such action has taken place to any great extent.

Main Body of Dock.

The necessity of placing the transverse braces to keep the bulkheads in place, materially changed the general scheme of construction, in so far as it applied to the work on the main body of the dock. The presence of these braces made it impossible to use a pile driver on the dock floor level, and by the time work had actually started here, there had accumulated from five to ten feet of mud, gravel and oyster shells in the bottom of the basin.

The pile drivers were placed on run-ways laid on top of these transverse braces, and from this elevation, the piles for the bottom and the side slopes of the first 200 feet of dock length, were driven.

Meanwhile excavation was being completed to the final elevation of pile cut-off, and as fast as a portion could be cleared, the piles would be cut and capped, and the 70 foot cross floor timbers placed in position. The piles driven from the elevation of the temporary braces, shown above, were found to be badly out of line at the point of cut-off, some so badly out, that it was necessary to cut them off a foot lower and cross cap them, in order to obtain any bearing.

The north bulkhead had given such evidence of instability that it was thought inadvisable to trust entirely to the earth back filling for security, so before the temporary bracing had been removed, a mass of concrete was packed in behind the altars and slope timbers, which, starting at the point of the first angle of the dock (80 feet from the abutments), was gradually increased in thickness, until it met the bulkhead some 20 feet back from the masonry, from which point the entire space behind the slopes was filled, until it reached the concrete backing of the masonry.

The cross drain was originally designed to be of plank construction similar in character to the side drains, but was

ructed in concrete, the foundation work of the aprons being
ded into the body of the dock for the purpose.
When sufficient flooring had been placed, a traveller was
ged, which had a derrick on the two forward corners, the
s of which could reach the surface level on either side of the
This was used in landing the heavy cross floor timbers and
slopes, and proved to be a very useful affair.
t was originally planned to face the side slope timbers with
nch white pine boards, over which the altars would be spiked,
fter facing a small portion, these boards were entirely omitted
the remainder.
Their use necessitated hewing the entire back surface of the
s, in order to keep the front surfaces to the required lines,
it was also thought that these boards would serve to retain
behind the slopes, after the dock had been pumped out, and
radual drainage of this into the slopes would keep the altars
y and slippery most of the time.
The soft mud and gravel removed from the bottom of the dock,
placed or rather dropped from buckets behind the slopes, as
as altars could be placed to retain it. It would have been
preferable to have carried this material entirely away, and
ded a better kind. Many times this semi-liquid mass broke
gh temporary retaining walls and came pouring back on the
floor. Its use caused a considerable inward bow in the slope
ers at one point, and at another near the first angle in the
side, when the filling had reached nearly to the coping, the
ure was sufficient to force the slope timbers from the piles,
seriously threaten to overturn that portion of the slope.
y iron tie rods were immediately placed so as to fasten the
timbers back to the bulkhead, and the addition of filling
stopped until that portion already placed had entirely dried

The north bulkhead at one point for a distance of some fifty
had crowded so far into the dock that it was within the
ed coping line. As it was impossible to get it back again,
top was sawed away and the finishing timbers laid upon it,
ad of the pile capping. It seems to have kept to this position
since, so no harm has resulted from the compromise.
When construction work had progressed to the point where the
nal shore line was located, the most difficult portion of the
was over. The hydraulic pressure against the bulkheads
no longer to be reckoned with, and the temporary braces
ng been taken down, a free field was left for the pile drivers
the traveller.

The drivers were now landed on the dock bottom, and th rows of piles from this point became more satisfactory.

The excavation was mostly in the gravel strata above th white clay, and a number of springs were encountered, which fo a time sent water and filling up through the crevices in the flooring but gradually ceased to flow, or found their way into the lowe level of the side drains.

At the extreme head of the dock, however, a very serion spring was encountered, which it was impossible to check. Th flow from this source would approximate that from a 5 inch pip under moderate head. After various attempts to choke it bad with concrete and cement, all of which were unsuccessful, th stream was piped into the nearest side drain and allowed to run This will be referred to a little later, as the owners of the dock after they came to operate it, tried their hand at controlling thi stream.

About the head of the dock, the sand and gravel soil became so compacted that it was practically impossible to drive the slope piles. The top row was driven, after a fashion, however, through the surface soil, and from this point to the foot of the slope, the banks were cut to slope of the side timbers. As the altars were placed, concrete was rammed between them and the bank, in place of earth filling.

It was originally planned to have the head of the dock, a slope, similar to the sides, but this was modified in part, and a box-like projection constructed, which gave an additional 24 feet 3 inches to the effective working length of the dock.

The driving of the protection sheet piling about the head of the dock was abandoned, owing to the hard subsoil, and in its place was constructed a masonry retaining wall, to support the city street which passes close to the head of the dock, but at a higher level.

By this time the keel and bilge blocks had been placed and the dock allowed to slowly fill by leakage. The cofferdam was pulled, and the entrance dredged out to the level of the aprons.

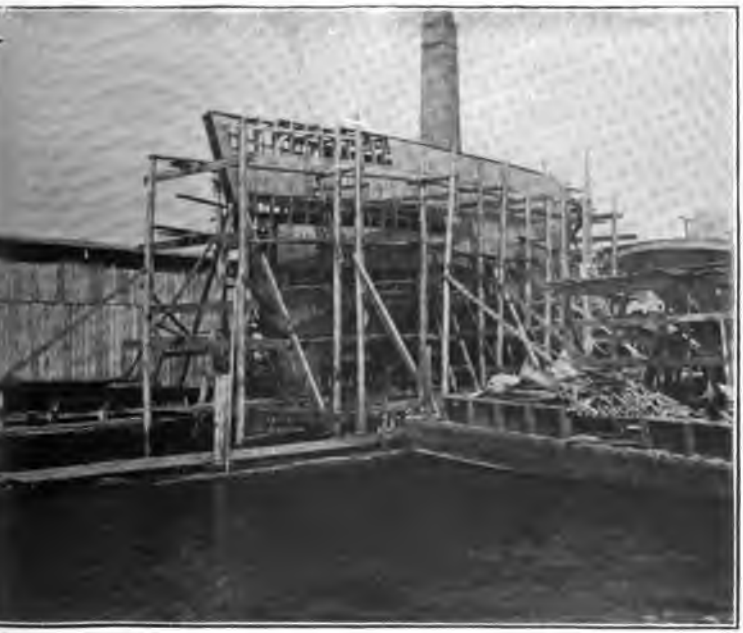
The dock was completed and formally opened on the 25th of November, 1901, thus making the total time of construction a trifle less then 2 years and 3 months. There had been used in the work an amount of material approximately as follows:

Yellow Pine Sheet Piling..	1,100,000 ft. B.M
Yellow Pine Timber..	1,028,000 " " "
White Oak Planking..	112,000 " " "
White Oak Timber..	82,000 " " "

WING METHOD OF SETTING ANCHOR BOLTS FOR ENGINE BASES.

COMPLETE SETTING OF SUCTION PIPES AND ANCHOR BOLTS.

THE FORMAL OPENING, NOVEMBER 25, 1901.
A 300-FOOT STEAMER IN DOCK.



THE CAISSON-GATE (SHEWING CONSTRUCTION).

on Fir Timber	114,000	ft. B.M.
te Pine Boards	4,600	" " "
l Bands	4,100	lbs.
l I beams	2,600	"
Tie Rods	52,000	"
Granite Masonry	22,000	cu. ft.
crete	180,000	" "
nd Piles	933,000	lin. "

And in addition there had been 30,000 cu. yds., of Excavatfon 60,000 cu. yds., of Dredging.

Cost Data.

The contract for this work was let on the basis of unit prices material in place, and labor performed, as per the following dule:

lging	32c.	per cu. yd.
avation	37c.	" " "
t Piling	$ 53,25	" ft. B.M.
ow Pine Timber	37.60	" " "
te Pine Boards	35.60	" " "
on Fir Timber	26.00	" " "
te Oak Plant	38.00	" " "
nd Piles	15c.	" lin. ft.
Rods	4c.	" lb.
l Bands	5c.	" "
ams	4 ⅗ c.	" "
crete	21c.	" cu. ft.
Granite	1.09	" " "

The total cost of the complete dock was $430,000.00.

Aside from the carpenter force, which was more or less skilled or, the working force consisted of negros and foreigners, cipally Bohemians. It is the writer's opinion, that the ordinary red gentlemen, when viewed from the standpoint of reliability a workman, is a failure. Pay days on this job were twice a nth, and after each one, the personnel of the laboring force ld contain about 75% of unfamiliar faces. Two weeks steady k was about the limit.

Wages for a ten hour day's work were approximately as ows:

Foremen	$3.50
Carpenters	2.25
Carpenters' Helpers	1.75
Engineers	2.00
Firemen	1.75
Common Laborers	1.50

The contractor's claims for "extras" on this work reached an enormous total. Unfortunately, in the specifications, no provision had been made for the possible need of temporary bracing. When the protection bulkheads started into the dock, temporary bracing became absolutely necessary, the placing of which the contractor of course claimed to be outside the scope of his contract. A compromise was effected whereby the contractor was to place and remove all needful bracing, using therefor timbers that could later be placed permanently in the dock. For this labor the contractor was to charge extra time, and for the material be allowed a certain percentage of its contract value, until such time as it should be placed in final position in the work.

No one could have foreseen the great amount of time that would be necessary to accomplish this, or the consequent extra cost.

It is seldom that a work of this extent does not cost human life as well as money, and the writer would be pleased were it possible for him to state that this was an exception to the usual rule, but such was not the fact. Two workmen were killed. Of narrow escapes there were several, such as when a pile driver overturned, and a hoisting bucket full of mud fell back among a gang of shovellers. Of the less serious accidents, we might mention that of a member of the Engineering staff, who stepping off a timber one day, found himself up to his shoulders in the rich black ooze at the dock bottom.

Comparison With Other Large Docks.

It may now be of interest to record the finished dimensions of this dry dock, and compare it briefly with the other large structures of similar nature to be found along the North Atlantic seaboard.

In looking over the published literature bearing upon this subject, it is at once evident that there is needed a more systematic method of recording the dimensions of docks, whereby measurements may become directly comparable. One writer in describing a structure will note that "the length on the floor, head to inner abutment is 516 feet" while another states that "extreme length at bottom on keel blocks is 568 feet".

The purpose of a dry dock is to dock vessels, therefore the first principal dimension of a dock, should be given as that of the longest possible boat which the structure would be able to accommodate, or in other words, the greatest horizontal distance, measured along the level of the tops of the keel blocks, from a vertical line tangent to the inner face of the caisson gate, to the corresponding point in the head of the dock. Next in importance is the minimum depth of water over the entrance sills, after which

CONCRETE MIXER.

l be given the width of entrance at the level of the top of ighest sill, the vertical distance from the top of this sill coping level, and the width of entrance at this level. In ody of the dock, dimensions should be given as follows: ium width on floor level and at the level of the top of locks, maximum width at coping level between the inside of the coping timbers, and horizontal distance at coping from vertical tangent to inner face of caisson to the inner the coping timber at the head of the dock.

llowing this method, the finished dimensions of the Balti- lock are as follows:

e horizontal distance at level of keel blocks, from a vertical t to the inner side of the caisson, to the vertical face of the the head is 599 feet 4 inches. There is over the inner sill low tide, 22 feet of water, and at high tide, 25½ feet has ecorded. The width of entrance at the level of the top of ier sill is 60 feet, and at the coping level, 80 feet. The top inner sill is 29 feet below the coping level. The maximum of dock body is 60 ft. at the floor level, and 69 feet at level s of the keel blocks. The maximum width at coping level ft. between inner faces of the coping timbers. The over nension at coping level, from tangent to the caisson, to ace of coping timbers at the dock head is 604 feet 7 inches.

e other large docks along the Atlantic seaboard are located e following points: St. Johns, Nfld.; Halifax, N. S.; outh, N.H.; Boston, Mass.; Brooklyn, N.Y.; League Island, ewport News, Va.; Norfolk, Va.; and Port Royal, S.C.

the following table, the writer has compiled, from various , the principal characteristics of these. The indefiniteness two leading dimensions will emphasize what has just been regarding the desirability of a more uniform system.

TABLE SHOWING CHARACTERISTICS OF THE PRINCIPAL DRY DOCKS TO BE FOUND ON THE NORTH ATLANTIC SEABOARD.

Location.	Character of the Structure.	Year when Completed.	Time spent in Construction.	Cost.	Length (coping level).	Length (on floor).	Width—body (coping level).	Width—body (floor level).	Width—entrance (coping level).	Width—entrance (sill level).	Depth of Sill below coping level.	Depth of Water over Sill.
St. Johns, Nfld.	Concrete & Timber	1884	2 years	$550,000 *b*	600′ *c*	558′ *k*	132′ 4″	49′ 10″				25′ H.T.
Halifax, N.S.....	Stone and Concrete	1889	3 years	$750,000	600′ *d*	560′ *l*	102′	70′	89′ 6″	81′	34′ 6″	30′ H.T.
Portsmouth, N.H.	Granite & Concrete			$1,089,000 *b*	775 *f*	725′	130′	80′				30′ H.T.
Boston, Mass, No. 1 .. .	Granite	1833	5 years	$677,000	396′ 5″ *g*	367′ 5″ *m*	80′	30′	60′	44′	30′	25′ H.T.
" " No. 2 ..	Granite & Concrete			$1.025,000 *b*	750′ *h*	729′ *h*	114′	72′	101′ 8⅝″		35′ 2″	30′ M. H.W.
Brooklyn, N.Y., No. 1..	Granite	1851	7 years	$2,241,000	369′ 3″ *g*	333′ 3″ *m*	100′	30′	66′	48′	30′	25′ H.T.
" " No. 2..	Timber *a*	1890	3 years	$565,892 *b*	500′ *i*		130′ 4″	50′	85′		30′ 6″	
" " No. 3..	Timber	1897			600′ *h*	556′ *h*	151′	64′	105′	70′	33′	28′ M. H.W.
League Island, Pa.	Timber	1391			500′ *g*	459′ 8″ *m*			85′			25′ 5″ H.T.
Baltimore, Md...	Timber	1901	2 yrs. 3 mo.	$430,000	604′ 7″ *j*	599′ 4″ *n*	125′ *o*	60′	80′	60′	29′	25′ 5″ H.T.
Newport News, Va, No. 1	Timber				638′ 6″ *g*	573′ *m*	130′	49′	96′ 3″	50′		24′ 5″
" " " " No. 2	Timber	1901			860′ 5″ *g*	804′ *m*	162′	80′	114′	84′		30′
Norfolk, Va., No. 1... .	Granite	1833		$945,676	331′ 8″ *g*	302′ 8″ *m*	86′	30′	60′	44′	30′	25′ H.T.
" " " 2.....	Timber				500′ *g*	459′ 8″ *m*			85′			25′ 5″ H.T.
Port Royal, S C.	Timber	1895	4 years	$418,915 *b*	496′ *n*	459′ *m*			97′			26′ 0″ H.T.

NOTES:

a. Rebuilt in granite and concrete in 1902.
b Contract price.
c. "Head to caisson in outer sill."
d. "Head to outer groove."
e. "Head to gate in outer groove."
f. "Over all."
g "Extreme length."
h "Head to outer gate sill."
i. "Inside caisson."
j. From inner face of caisson, when in outer groove, to inner face of the coping timbers at dock head.
k. "On the keel blocks."
l. "On bottom, head to inner groove."
m. "On bottom."
n. "On the keel blocks from inner face of caisson when in outer groove, to vertical face of box in dock head."
o Best width between inner faces of coping timbers.

SHEWING RESULT OF PRESSURE, DUE TO SEMI-LIQUID BACKFILLING.

By a study of the table, it is seen that in maximum length docking facility, the Baltimore dock is only exceeded by dock mber 2 at Newport News, dock number 2 at Boston, and the ited States government dock at Portsmouth.

The Portsmouth and Boston docks were still under construction the time the Baltimore Dock was completed, so that at the time opening, it could rank as the second largest dock on the coast.

When we consider the serious mishaps that have attended e construction of some of these docks, and the length of time quired for their completion, we find that the Baltimore dock s built within a reasonable time, at a not excessive cost, and s practically free from misfortune.

The timber dock at Port Royal was under construction for a riod of four years, during which time the cofferdam gave way, e dock floor was lifted by the hydraulic pressure, and the dock s flooded by the tidal wave of August 1893.

Though the contract price given in the table is only $418,915, has been stated that the dock cost the United States government wards of one million dollars, including site and repairs, and a cent report states that it is to be abandoned entirely.

In the new Boston dock the cofferdam failed twice during nstruction, at one time a length of 200 feet giving way, and at other time the dock was flooded and all work stopped, due to a ttlement and overflow of the clay banking at the sides.

The two timber docks at Brooklyn have been the cause of any anxious moments on the part of the officials in charge. here has been leaks which were estimated at 10,000 gallons per inute.

Dock number 2, after nine years or so of use, failed so seriously at in 1900 it was almost completely rebuilt in concrete and asonry, and can hardly be classed at this time as a timber dock.

Conclusion.

The Baltimore dock has now been in operation for nearly ree and a half years, and it may be of interest, in conclusion, see what the result has been.

Through the concrete backing and the joints of the granite butments, at the time of completion, there were several places here small streams of water had found entrance into the dock. was thought at the time, that these streams of muddy water ould gradually deposit enough silt to choke back the flow, but ch has not been the case. The leakage through the concrete, emains about the same, no worse than at first and no better.

The 3 inch mortar course about the engine pit has proved effective. There are several damp places, but at no point can running water be seen, and what dampness there is, shows in horizontal lines around the engine room, and is evidently caused by an incomplete bond between one day's work on this mortar course, and the next.

The concrete placed between the altars and the north bulkhead, has served to keep the bulkhead in place, but at this point there is more leakage through the altars than at others. Since the filling has become compacted, there have been no visible signs of movement either in the bulkheads or the slopes of the basin.

The large stream of water at the head of the dock, (mention of which has been previously made) gave considerable trouble, in that it brought with it quantities of fine sand which choked up the side drains. After various attempts to control it, a test well was drilled, which showed that at a depth of 65 to 80 feet below the coping level, there existed a stratum of coarse gravel, and rock at a depth of 132 feet. Three ten inch pipes were driven to the rock, and perforated where they passed through the gravel stratum.

These wells are pumped by compressed air and the work has to go on constantly whenever the dock is being used.

At the outlet of the pumps, where the sluice way was omitted, there has been no evidence of scour about the feet of the sheet piles. The drainage system has proved of ample size for the work intended.

The shortest time in which the dock has ever been pumped out with all three pumps running, is 70 minutes. With two pumps going, as is usually done, it can be emptied in 90 minutes.

There is no doubt that in the designing and building of this dock, many things would have been done otherwise, could foresight only have been as keen as hindsight. But after all is said and done, can there be a better test of the success of an engineering work, than that it satisfactorily performs the functions for which it was designed?

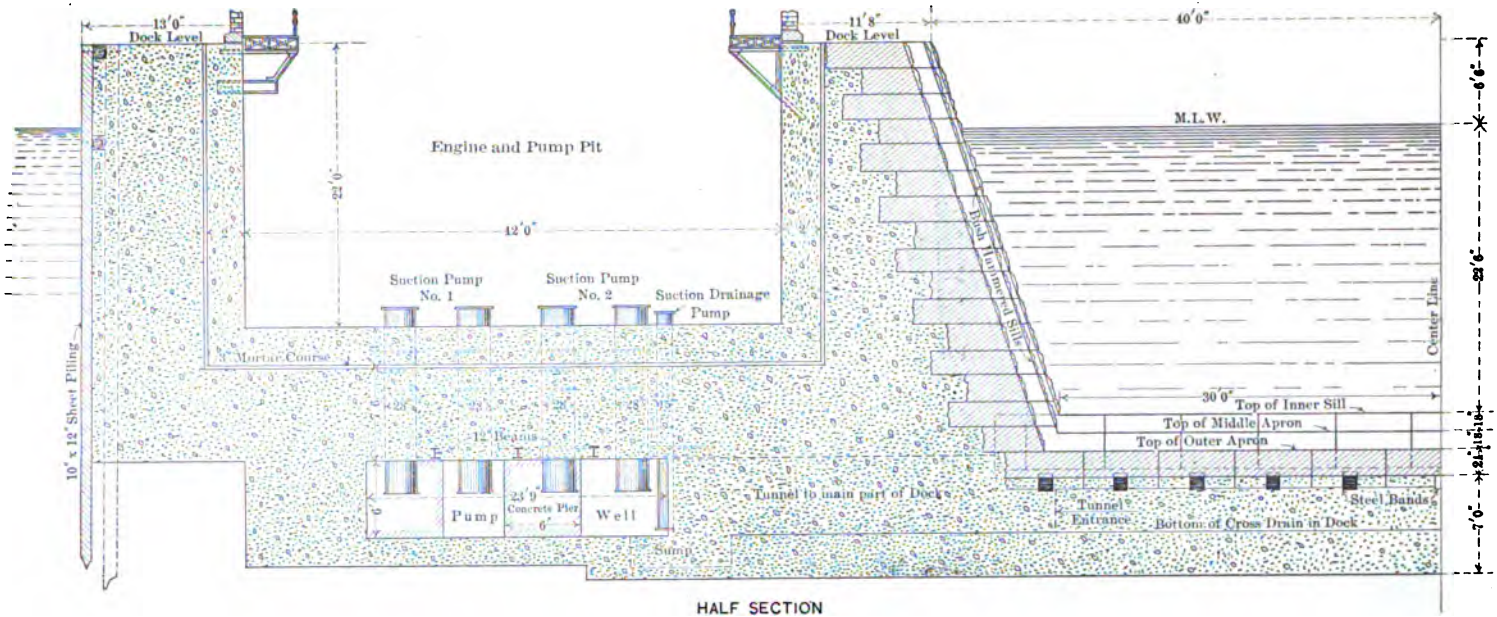
The writer concludes this paper with the words of the President of the Company, who in a recent letter to the author took occasion to say, "In our three years operating the dock, we have made but one change, and that was to lengthen the smoke stack so as to cut out forced draft, otherwise if I had another dock to build, I would not make any change whatever."

THE WM SKINNER & SONS CO.

BALTIMORE, MD.

DRY DOCK.

SECTION



HALF SECTION

DOCK ENTRANCE AND POWER HOUSE

DISCUSSION.

Mr. Shanley.

Mr. Shanley asked whether any precautions had been taken to protect the timber against the teredo.

Mr. Ashcroft.

Mr. Ashcroft answered that at that point the water was only slightly brackish, since there were one or two fresh water streams entering there. An old dock near which had been used for about twenty years, was in a very bad state of repair, but the decay was simply the rotting of the timbers, and not from the effect of the teredo. Farther down the Bay there would probably have been trouble experienced from the teredo.

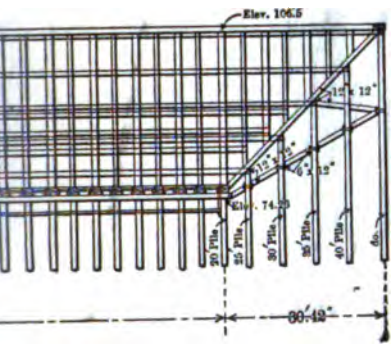
Dr. W. B. Dawson.

Dr. W. Bell Dawson added, by correspondence, that in comparing the capacity of dry docks, Mr. Ashcroft was very right in emphasizing the need for taking standard dimensions, which were comparable in all cases. Mr. Ashcroft had also considered that the depth of water over the entrance sill was the dimension next in importance to the length of the dock; but he was surely in error in adopting the minimum depth, or the available draft at low water, as the term of comparison. This might perhaps be allowable where the tide had a very small range, amounting only to two or three feet, as in the case of the dock at Baltimore, which he was describing, but where the tide had a greater range, it was the universal practice, both in Europe and on this continent, to admit vessels at high water, in order to take advantage of the additional draught then available. In some of the important Canadian harbors there was a tidal range of 18 to 24 feet, which it would be quite out of the question to overlook, or to lose the advantage of. It was also to be noted that where the rise of the tide was so great, it was not possible to open the dock gates except at high or low water, on account of the rapid change in the water level.

Mr. Shanley.

Mr. Ashcroft.

Dr. W. B. Dawso

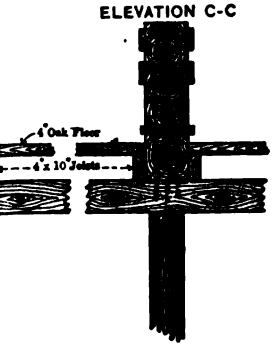


NNER & SONS' CO.
TIMORE MD.

RY DOCK.
DETAILS.

D-D'

ELEVATION C-C



Mr. Shanley.

Mr. Ashcroft

Dr. W. H. Dai

PAPER No. 228.

THE BOUT DE L'ISLE BRIDGE.

By J. L. Morris, M. Can. Soc. C. E.

The Bout de l'Isle Bridge, though not forming one of the list of the International and Interprovincial bridges, as yet few in number, has claims to be classed with the prominent bridges of Canada.

It is composed of two crossings over the east and west branches of the Ottawa River, formed by Ile Bourdon, just above the junction with the St. Lawrence River at the foot of the Island of Montreal.

The location is practically the same as determined by the engineers of the Quebec, Montreal, Ottawa & Occidental Railway, as an alternative crossing of the Ottawa River for an entrance into Montreal for the through line from Quebec in 1874. This bridge now forms the crossing of the Ottawa River, for the Chateauguay and Northern Railway Company, on their line from the City of Montreal, to the Town of Joliette on the line of the Great Northern Railway, which now forms that part of the transcontinental line of the Mackenzie and Mann system which connects Quebec and Hawkesbury.

The west channel, that between the Island of Montreal and Ile Bourdon, is about 1500 feet in width, and the bridge crossing it comprises the following spans:—a deck plate girder 46 feet in length between the west abutment and pier No. 1; four through trusses each 140 feet in length from pier No. 1 to pier No. 5; a through truss 200 feet in length from pier No. 5 to pier No. 6; four through trusses each 140 feet in length from pier No. 6 to pier No. 10; and a deck plate girder 46 feet in length between pier No. 10 and the east abutment.

The distance across Ile Bourdon, between the abutments of the west and east channels is about 2100 feet.

The east channel, that between Ile Bourdon and Charlemagne is about 1300 feet in width, and is crossed by the following spans; a deck plate girder 70 feet in length between the west abutment and pier No. 1.

Seven through truss bridges each 140 feet in length from pier No. 1 to pier No. 8; a deck plate girder 70 feet in length between pier No. 8 and the East abutment.

The 2100 feet stretch across Ile Bourdon, is composed of earth embankment, while at the other end of both crossings, the approaches are built of temporary trestles, each about 2000 feet in length.

The original contract for the sub-structure of the bridge was let to F. C. Dunn and Company of New York in 1902, who not being in a position to construct owing to the great hazards to be met with in the work, sub-let to the W. J. Poupore Company of Montreal in February 1903 all of the work coming under their contract with The Chateauguay and Northern Railway Company, being twenty five miles of railway line, which included the sub-structure of the Bout de l'Isle bridge.

Preliminary construction such as the cutting off of piles and the building of caissons was begun in the month of February, and continued until the 18th of March, when the breaking up of the ice compelled the Contractor to stop work until the Spring freshet had subsided, and the water had fallen in the St. Lawrence River. Much of this preliminary work was injured by the action of the ice, which was carried past the site in large blocks by the swift current.

Piles for the foundations of all piers and abutments were driven at about three feet centres, and this work was carried on during the winter of 1902-3 from the ice, which notwithstanding the strong current, formed to a good thickness, and made this part of the work an easy matter, especially as the material in the bed of the river caused no inconvenience in the driving of the piles, being of a stiff blue clay.

The Chateauguay and Northern Railway Company being responsible for the cutting off of the piles, as required for the foundations of the piers and abutments, made an effort to cut the piles of pier No. 4 by using one diver from an anchored scow. Owing to the swiftness of the current this was found to be impracticable, and the balance of this part of the work was carried out by the W. J. Poupore Company, who to ensure the safety of the men employed below water, took all the precautions which were possible. A large scow was securely snubbed to the heads of the piles, which came near to the surface of the water. Just above the piles upstream from the pier a temporary crib triangular in shape was sunk with the nosing upstream, which broke the current and caused practically still water around the piles. Even with this advantage it was considered inadvisable to use one diver in cutting the piles, and two were used in preference. As many as twenty four piles per day were cut off about 18 inches above the level of the bed of the river.

The foundations of the east and west abutments, and piers 1, 2, 3, 9, and 10 of the west channel, were constructed, together with all the foundations of the east channel by building cofferdams. Piers 4, 5, 6, 7, and 8 of the west channel had their foundations constructed by the use of caissons. These caissons were constructed 18 inches larger on all sides than the required dimensions of the concrete foundation of the pier, with 12″ x 12″ squared timber, well braced on the inside, then all joints well caulked so as to make it watertight.

The timbers were scribed to fit the bottom of the stream at the site where the caisson was to be sunk.

At the placing of the caisson for pier 4, it was thought possible to anchor it in place by the use of three ship anchors, attached with cables to the nosing and corners of the caisson, but owing to the swiftness of the current and the slippery condition of the clay in the bottom of the stream it was found impossible to do so, and no effort was made afterwards to place any of the piers with them. It was at this pier No. 4, that owing to the anchors slipping, the caisson capsized and threw the men into the water. All the five caissons were finally placed by means of two cables attached to trees on an island about 2500 feet above the bridge site, and as a protection to the public were floated on cedar poles with spaces of about 30 feet between them, and attached one on each side of the caisson, and with a third cable against the current from the nearest pier on the work, we were able without mishap to place all of the caissons.

At the shore ends where the water was shallow and where cofferdams were used the concrete was brought to its finished level without delay, as there was no difficulty in keeping out the water from the cofferdams, but in those foundations where caissons were used, the concrete was filled under water to within five or six feet of the required level, and after five or six days the water was pumped out and the balance of the concrete brought to a finished level.

After the placing of the caisson and before any concrete was filled in, the diver made a careful examination of the bed of the river within it, and of its bearing on the bottom. The only difficulty was with pier 5, which did not fit the irregular bottom, and it was necessary to line the inside of the pier with heavy canvas, and place concrete in bags around the inside edge of the caisson to stop the flow of the water through the concrete, and prevent the carrying away of the cement and sand.

The concrete used in the foundations was composed of 1 part of cement, 2 parts of sand, and 5 parts of broken stone. The brands of cement principally used were Invisible (a Canadian cement) Dyckerhoff, and Haemoor (both German cements).

The supply of crushed stone was brought from the quarries of the W. J. Poupore Co., at the east end of Montreal, and delivered to the work on large scows.

The level of the finished concrete in the foundations was 1 foot below the low water level for piers 2, 3, 4, 5, 6, 7, 8, and 9 of the west channel, and for all piers in the east channel. The abutments of both crossings were 44 feet in width, 22 feet and 6 inches from the top of the concrete to the bridge seat, and 5 feet from the bridge seat to the top of ballast wall. The thickness of the abutment at the

bridge seat was 6 feet, the front wall having a
Piers 1 and 10 in the west channel were 27 feet an
above the concrete, with a width of 6 feet at th
of 1 in 24 on all sides, the bridge seats for the
lower than for the shorter spans bearing on these p
end of all piers have cutwaters commencing a
concrete foundation and reaching to within abou
level of the bridge seat. The lower or down strea
are circular, and so carried up to the bridge seat

Piers 2, 3, 4, 5, 6, 7, 8, and 9 of the west c
constructed, all being 30 feet in height above the
to the bridge seat level, 6 feet in thickness at t
with a batter of 1 in 24. The piers 1 to 8 inclusive
crossing are all 25 feet in height above the co
bridge seat, 6 feet in width at the bridge seat, a
1 in 24. These piers were otherwise built simila
West Channel.

All stone supplied for the masonry of this br
Terrebonne quarries in courses ranging from 18
thickness, and is a good quality of limestone fo
The mortar used in the work was composed of
and two parts of sand.

Much expense was incurred in the handling
was first unloaded from the cars at the west end o
and distributed from this point by lorry cars to
and then loaded on scows and towed to the p
This necessitated, especially during the low water
wharves at both shores of the two crossings, and a
these had to be further carried out so as to give
to float scows and tugs.

At the latter part of the season the water
became very shallow, and the larger scows could
the site of the bridge, when loaded with building
place was made about 1000 feet below the crossin
transferred to smaller scows, and towed to the
very light draught. This necessarily caused co
carrying on the work. The Engineers of the
Northern Railway laid out all work without usin
the placing of caissons and the centering of pie
practicable, by having good ice to work upon duri
making use of the piling of the foundation of the
cases came near to the surface of the water, a
Engineers making steel tape measurements from
measurements given by the Engineers worked out
as to centre and span.

The first masonry of the west channel was laid on April 1st 1903, on September 10th of the same year the substructure was plete comprising 2 abutments and 10 piers, which contained 2138 c yards of concrete in foundations, and 2983 cubic yards of onry. The steel work was completed over this channel about the day of October.

The masonry of the east channel was commenced on August the 1903, and completed on November the 15th 1903, comprising 2 tments and 8 piers which contain 600 cubic yards of concrete in ndations, and 2060 cubic yards of masonry.

On the 25 miles of Railway construction between Bout de l'Isle Joliette four smaller bridges and seven arch culverts were built the same time as the Bout de l'Isle, and contained 3500 cubic ls of concrete.

BUSINESS MEETING.

A business meeting of the Society for th
for the election of members was held on Thur
Mr. Phelps Johnson in the chair. Messrs. J.
Jamieson, C. H. McLeod and G. Legrand ha
scrutineers, declared the following elected:—

HONORARY MEMBER.

THE RIGHT HONORABLE EARL GREY,

MEMBERS.

F. F. BUSTEED. J

ASSOCIATE MEMBERS.

M. B. ALMON. S
J. E. BEATTY. J
R. M. CHARLTON. I
CRAVEN GARNETT.

TRANSFERRED FROM CLASS OF ASSOCIATE M
OF MEMBER.

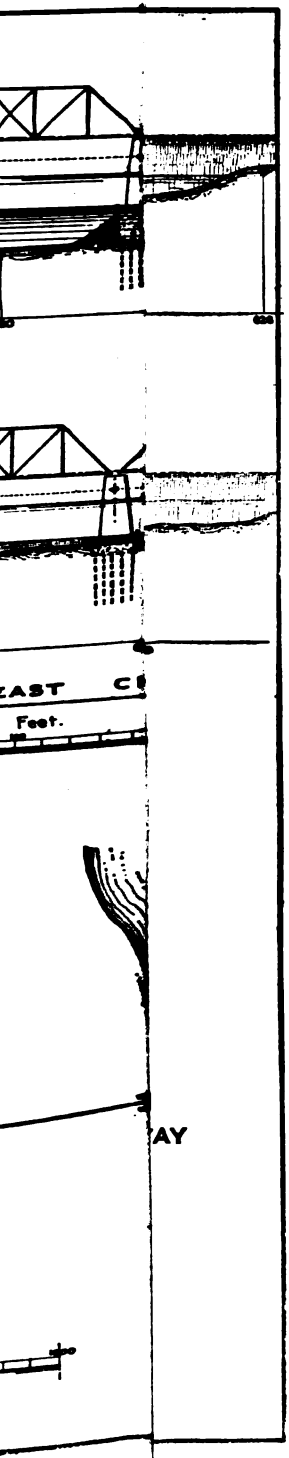
E. A. HEBERT. C
J. O. A. LAFOREST. F
H. R. LORDLY. D

TRANSFERRED FROM CLASS OF STUDENT
ASSOCIATE MEMBER.

A. S. COOK. J. T. F
W. A. DUFF. H. J. A
H. P. RUST.

STUDENTS.

C. D. G. BOOTH. S. S. M
A. V. CHASE. A. K. I
W. R. DEVENISH. W. W.
S. A. DESMEULES. G. G. M
G. W. F. EVANS. E. N. I
E. O. FUCE. N. D. V
E. S. HOLLOWAY. F. S. W
L. E. H. LIPPE.


EAST
Feet.
AY

PAPER No. 229.

AN INVESTIGATION OF A 16 K. W. CONSTANT CURRENT TRANSFORMER.

By C. H. Wright, S. Can. Soc. C. E.

Introductory.

The principle of a constant current transformer was first described in a paper presented before the American Institute of Electrical Engineers by Professor Elihu Thomson, on May 18th, 1887, and published in the "Proceedings" of that body in the London "Electrician." Following this there appeared in the London "Electrical Review" of April 16th, 1887, an article by Professor Thomson, describing the effects of replusion between primary and secondary, and entitled "New methods of regulating current and potential in secondary of transformers." On January 10th, 1889, an application was filed for a patent on constant current transformers which regulated by means of a variable magnetic leakage, the opportunity for leakage being intentionally made very great by winding the primary and secondary on the separate legs of an iron core, and so shaping the core that a great many of the lines generated by the primary could divert themselves from interlinking the secondary. An application was filed June 8th, 1891, for a patent on a constant current transformer which regulated by the variable leakage produced by a moveable secondary, and later for one with both primary and secondary moving differentially, the principle being essentially that of the present type.

Description and Method of Operation.

The component parts of the 16 K. W. or 25 light constant current transformer tested are:—

(1) A laminated iron core of the double magnetic circuit type, but of an exaggerated height, and of a ш shape, the top cross pieces being driven in after the coils were in place. The whole core is mechanically strengthened by iron castings at top and bottom, connected by wrought iron stay bolts and buck staves.

(2) A primary coil of 282 turns, rectangular in plan, and firmly fastened in the bottom of the spaces within the iron circuit.

(3) A secondary coil of 615 turns, rectangular in plan and fitted at each end with a brass casting, by which the coil may be moved bodily up and down the central part of the iron core.

(4) A lever pivoted on two knife-edges; with circular arcs, from which the seconda chain, and on the other end with an involu may be adjusted. From the involute is susp table weights, whose function is to nearly the suspended secondary.

(5) A tank of convoluted cast iron, or This tank is nearly filled with a special oil, as an insulator, but also as a mechanical dar to the movements of the secondary.

The following data were taken from the

No. 257149.

Specification No. 12216.

Type R.

Form A E′.

Cycles $\frac{60}{125}$

Kilowatts 18.

Primary volts 1100.

Secondary Amps. 6.6.

This transformer is designed to operate sequently must furnish a constant current w ing as to maintain this current irrespectiv external circuit. The primary is run fro mains, and so the method of variable leak regulation.

With the coils in any given position the simple static transformer, but with such a gre leakage that the ratio of the voltages calle turns is not attained. With the coils close load position, the flux generated by the embraced by the secondary, hence we have corresponding to 80 volts apiece for about 27 the external load to be decreased by cutting this voltage did not change, the current wo greater than the normal value of 6.6 amper action between primary and secondary would is so nearly balanced by the counter-weights, ing in the air, so this increased repulsion ca rise, thereby making a considerable area bet which leakage takes place. This leakage alone, the primary inductance is thereby incr lags farther behind the E. M. F. We now the secondary embracing fewer lines of fo generating a lower E. M. F., and by properly the E. M. F. can be made to be such as to at its normal value of 6.6 amperes. As the f

not vary in direct proportion to equal increments of secondary current, the involute is added to compensate for these variations.

In the extreme case, if the secondary be short circuited, the coils assume the no load position with the secondary at the top, and consequently the leakage is a maximum. On the other hand, should the external load be increased and the current be momentarily lowered, the repulsion would be lessened, and the secondary would move downward to a position where it embraced more lines, causing the voltage to rise.

It was mentioned above that the primary inductance increased in proportion to the amount of leakage. This brings out rather a remarkable result, for in the regulation test the primary current is seen to be practically the same for all loads, whereas the actual power supplied varies very closely with the load. The operation then is a result of a varying primary power factor, or a variation of the energy component of the current and the movement of the secondary into positions involving different leakage factors, but this does not involve a waste of energy in the primary except for losses.

Practically, the operation of the transformer depends upon the utilization of the variations in repulsion, between the primary and secondary as a mechanical means of producing a variation in the leakage factor. It was desired to analyze the workings of a transformer when regulating, and when blocked so as to prevent regulation. The data obtained are from runs made on lamps, pure non-inductive loads, and purely inductive loads. The different constants show the effects and defects of the regulation, and in many of these tests qualitative results were looked for rather than quantitative, as precision could not be expected with the low power factors reached in some of the runs.

Method of Making Tests.

Both primary and secondary were furnished with ammeter, voltmeter and wattmeter, the voltage of the second being reduced by potential transformers of variable ratios. The power was derived from the 10-pole motor driven generator run at 60 cycles in the shop, and also from one run compound. The first non-inductive run taken was with the compound machine. A set of different readings were taken from nine different blocked positions of the secondary, at current values varying from 10 to 1. From the values of each of these positions the apparent watts and power factors were also calculated, and plots were made according to 1, 3, 5, 9.

Inductive Load.

The first method employed as a means of obtaining a variable inductance, was to run the output into the primary or secondary

coils of a 50 light constant current transformer circuiting the remaining coils and varying their the inductance as to obtain desired readings precisely as in the non-inductive runs.

The next arrangement tried was that of coil so arranged as to be moveable on a thus capable of being associated with a variabl did not have a great enough range owing to sometimes used. From the values observed, and power factors calculated, sheets 2, 4, 6 and

Core Loss and Exciting Curr

This test was taken on the primary with Readings were taken of the voltage, amps., an conditions, the instruments being so arranged t ammeter and series coil of wattmeter shall be i coils in voltmeter and wattmeter.

The exciting current was about 6.6 amps.

VOLTS		WATTS	
Observed. —	Corr.	Observed. —	Corr.
110	110.4	48.4	439 Co
110	110.4	48.5	49.0
110	110.4	48.5	49.0
110	110.4	48.6	49.1
	110.4		49.0

The primary volts were thus too high wh error was taken into account. As the differe we may assume a straight line variation of voltage. Applying correction to the loss

$$\frac{\text{true loss}}{\text{observed loss}} = \frac{110}{110.4} = \frac{W}{490}$$

$$\therefore W = \frac{1100\ 490}{110.4} = 488, \text{ which is the true cor}$$

The copper loss in primary, due to this sma would be roughly

$$W.\ Cu. = (.66)^2\ (.1102) = C^2$$
$$= .048 \text{ watts.}$$

This is entirely negligible in the value 488, about ½ of 1%.

From value of exciting current and core lo the magnetizing current, for since the cur hysteresis is in phase with the electromotive

equal to the watts read divided by the E. M. F. read. This gives the value of the component in phase.

$$C = \frac{388}{1100} = .44 \text{ amps.}$$

Now the magnetization of the exciting current is in quadrature with the E. M. F., and as we have the mean square value of this exciting current for the ammeter

$$C = c - j\,c^2$$
$$.66 = .444 - j\,c^2$$
$$\therefore c^2 = .434 \text{ amps. magnetizing current.}$$

Core Loss Variation.

It seems very probable that there is a variation in the core loss from one position of the coils to another with the accompanying variations of leakage. As measured, the core loss is that due to a certain definite flux traversing the iron, and this is practically the whole flux generated, and as the current is drawn from the secondary some of this flux is diverted and, provided the coils are any distance apart, leaks across the air spaces of the yoke, so that the iron above the secondary coils is thus carrying less flux than it was when the core loss was measured.

All the iron, then, above the secondary, including the upper cross-piece of the yoke, is worked at lower density, and consequently the area of the hysteresis loop being less, the energy consumed must be less. This difference must grow less as the coils approach the full load position, as then the opportunities for leakage would be reduced, and more of the flux would have to pass through the secondary and through the upper portion of the iron circuit. At full load position the opportunity for leakage must be very small, so that the greater part of the flux would actually traverse the iron circuit, as at open circuit, but here the demagnetizing effect of the secondary is so disposed as to be in its most favorable position.

It would seem that the upper portion of the yoke was at all times merely carrying a differential flux, and that this difference was by no means constant. There appears to be no means of measuring this variation except by a determination of the total losses of the transformer by some method such as the ice calorimeter, and then subtracting the C^2R losses of primary and secondary secondary.

Heat Run.

The heat test was run at normal voltage, frequency and current, with two inch space between stationary and movable coil.

PRIMARY.

Hour A.M.	Temp. air.	Temp. oil.	Volts.	Amps.	R
8	18.3	18	110.0	14.9	.65
9	19.	23	110.0	14.8	.72
10	18.	27	110.0	14.8	.74
11	18.	30	110.0	14.7	.74
12	18.5	32	110.0	14.8	.75

SECONDARY.

2060	6.6	3.65
2080	6.6	3.97
2080	6.6	4.10
2060	6.6	4.16
2080	6.6	4.18

Remarks:—

Oil in tanks one-half hour before run.

Initial resistance taken without oil in tan

The resistance is calculated from $C = \frac{E}{R}$

The temperature rise was calculated from

$$T_r = (238 + t_1)\left[\frac{R_2}{R_1} - 1\right]$$

where T_r = temperature rise in C.

t_1 = average temperature of room du

R_1 = resistance hot.

R_2 = resistance cold.

The degrees rise were calculated fr resistance by the formula

Degree rise = K × % rise in degrees.

where $K = (1 + 25 + T)\ (2.5)$

$= (1 + .04)\ (2.5) = 2.60.$

IMPEDANCE.

The impedance is measured by observing rent on the primary when the secondary is primary voltage is, of course, lowered to suc the normal current of 6.6 amperes as rea ammeter. The impedance was measured by t tions of the secondary.

	Sec. current.	Prim. Volts.	Prim.
Coils apart	6.6	964	
" together	6.6	153	

The fact of having lowered the E. M. F. does not in any way affect the value of the impedance, as the inductance and periodicity are the only factors which enter into the component, and these, like the resistances, are constant specific properties of the primary at any given position of the secondary;—the latter, of course, carrying its normal current.

Reactance.

From the impedance and the value of the primary resistance, the reactance at the two points may be calculated.

$$Z_1 = r_1 - j\,x_1$$

$$65.5 = .1102 + j\,x_1$$

$$x_1 = \sqrt{(65.5)^2 - (\cdot 1102)^2}$$

$$= 65.5 \text{ ohms.}$$

This shows that even at full load the primary resistance is literally swamped by the reluctance, and that the impedance and reactance are practically synonomous.

Inductance.

The absolute inductance in henries may be calculated from the reactance and the frequency.

$$x_1 = 2\,n\,l_1$$

$$l_1 = \frac{x_1}{2} = \frac{65.5}{2 \times 3.142} = .141 \text{ henries.}$$

$$l_2 = \frac{x_2}{2n} = \frac{10.5}{2+3.142} = .0167 \text{ henries.}$$

A table of these constants of the primary is given below:—

Position of coils.	Periodicity.	Resist. in ohms.	Impedance.	Reactance in ohms.	Inductance in henries.
apart	60	.1102	65.5	65.5	.142
closed	60	.1102	10.5	10.5	.0167

Discussion of Results.

The tests made on lamp loads are the ordinary regulation tests, and readings were taken at each position, so that it was possible to plot curves on sheet 7.

The lamps used are known as the Form 3 series alternating current Thomson enclosed arc. They are of the differential type, the series and shunt magnets each consisting of two solenoids

placed side by side. The armatures are U sh
and are attached to opposite ends of a lever
carbon feed clutch. Adjustment for proper arc
80 volts, is by means of a sliding weight on thi
curve is seen to be very nearly a straight line
regulation, and the drop on 20% overload is
way in which this curve follows the voltage
shown, and the watt curve shows very plainl
increase of energy supplied. The drop in voltag
in current is not, however, due to decreased ef
as is shown by the change in direction of the
current starts to fall off, and also by the f
The secondary power factor appears to be highe
but does not drop below 85 even at 20% overlo
dotted ordinate is drawn at 25 lamps, and th
lamps, the latter being considered equivalent
This performance shows the transformer is ab
very wide ranges of load without a great chan
although the primary factor may drop as low
load, it is about 77 or 78% on full load, with
on overload. Considering that the power facto
lamps in the secondary circuit is 84, the intern
the transformer is seen to be reasonably small,
excess of copper losses introduced in transform
rator is inappreciable.

Non-Inductive Load.

The result of the runs on non-inductive los
any other what we may call the "intrinsic prop
former; primarily, because the variations of cur
proportional to the variations of actual energ
second place, because the generator compounds
such loads, and gives more approximately sine
because of the greater precision of the measurin
used on higher power factors. An inspection
how, with the coil blocked, an increase in the
causes a decrease in the secondary voltage du
magnetic leakage thereby resulting. This is sh
in the two lower curves, where the opportuni
great, the voltage falling to zero before the cu
great enough value to blow the fuse.

This effect becomes less and less pronounc
blocked nearer and nearer together, the path fo
less and less, and the transformer approachi
transformer type. All the curves up to the th

the top show a fall in voltage more than proportional to the increase in current and appearing convex upward; but above these two curves there is a pronounced tendency to a convex downward curve, the voltage not falling off proportionately to the increased current. The only probable explanation of this seems to lie in the fact that the space across which the magnetic leakage must take place is more constricted, and although leakage can and does take place, the area of the inside portions of the core legs from which the leakage must emerge is so small as to cause the iron at these points to approach saturation and force a proportionally greater number of the lines to link the secondary than would otherwise do so. If the area was infinitely small, no leakage could take place, and we would then have a pure static transformer, with constant secondary potential minus copper losses. The fourth curve from the top in Sheet 1 may be taken as the limiting case where the leakage is proportional to the increase in current and the plot is a straight line. This plot shows clearly how the transformer would act if the coils were not blocked. Suppose, for example, the current to be 6.6 amps. on a very light load, corresponding to a definite voltage on the lowest curve (about 800 volts); now an increase of load would momentarily cause the current to drop, and the coils would swing to a new point as represented on the curve above (about 1300 volts). Successive increments of load would cause the 6.6 amperes to travel from curve to curve until it finally reached the highest curve at a certain overload, beyond which point the transformer would no longer act as a constant current transformer, but increased load would mean decreased current, with but very slight increase of voltage up to the infinite load point of about 2100 volts. The watt curves on Sheet 3 are very interesting, and show a decided resemblance to the current curves in many respects. The four lower curves intersect at zero at the two points where the current and voltage, respectively, are equal to zero and, of course, all the other watt curves would do the same if the transformer had been able to carry the current required to pass through their complete cycles. These curves show a marked symmetry and, moreover, they all appear to have a maximum value of about 1400 volts, and to be symmetrical about the axis of 1400 volts. This could not be explained, but undoubtedly the proper equational relation, if differentiated, would show some such maxima, and it seems probable that this would be at 1200 volts instead of at 1400. It is also probable that the symmetry would disappear on the upper curves, due to the same cause as the upper bending of the current curve of Sheet 1. The two plots of Sheet 5 show very clearly the variation in power supplied, and in the power factor with the primary current. Both plots exhibit the general tendency in all the plots of the dropping away of energy

as the current tends to rise in the secondary ci
plot shows very graphically the actual power su
ferent positions of the secondary coil, and, toget
plot, the fact that low secondary loads mean a
of the power supplied to the primary, due to the
lower power factor. The upper curves of the lo
exactly such as would be obtained from a stati
the upper curve of the power factor curves is
occurs in all of them between the values of fou
This appears in every one of the nine curves
point, which, of course, involves readings at wid
on the instrument scales.

INDUCTIVE LOAD.

The runs on inductive load were intended t
of the transformer in different positions, when
most severe conditions as regards lagging curre
disproportionate heating involved. The load
purely inductive, as was described previously,
the decision of some of the readings, particula
was somewhat low, the results being shown in Sh

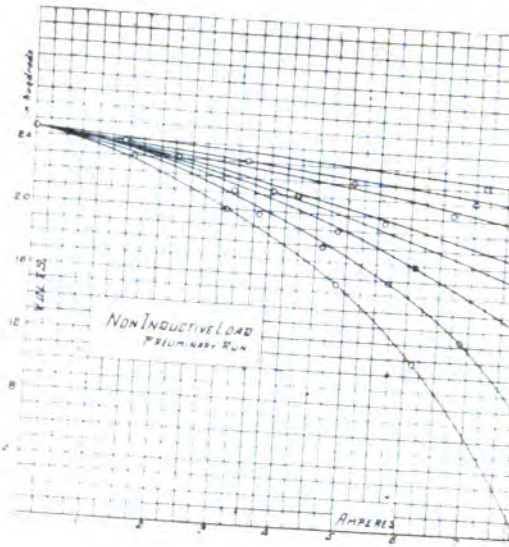
The curves in Sheet 2 showed a marked di
secondary obtained non-inductive curves in Shee
of voltage on increase of current being very nea
case, the slope of the line being greater in the lo
than in the higher and full load positions. T
clearly that the regulation on inductive loads wo
entirely on the movement of the coils, and that
be avoided on lamps on any load which it was
especially on full load or overload.

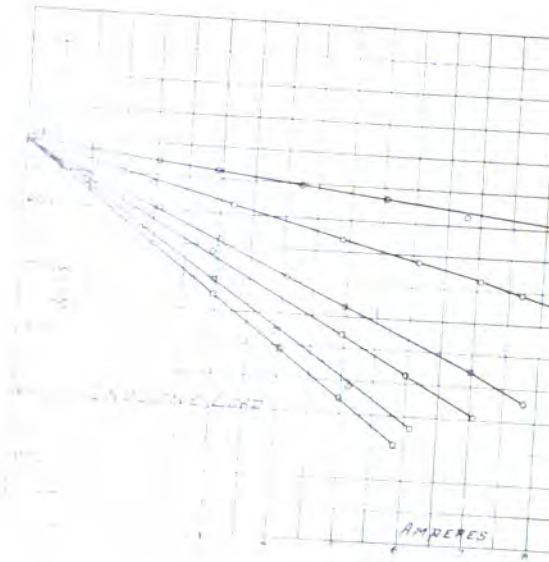
For the sake of comparison, an extra load ru
load was taken at the full load position and p
most curve in Sheet 2). The difference between
curve and the inductive load curve is most m
being very much more stable.

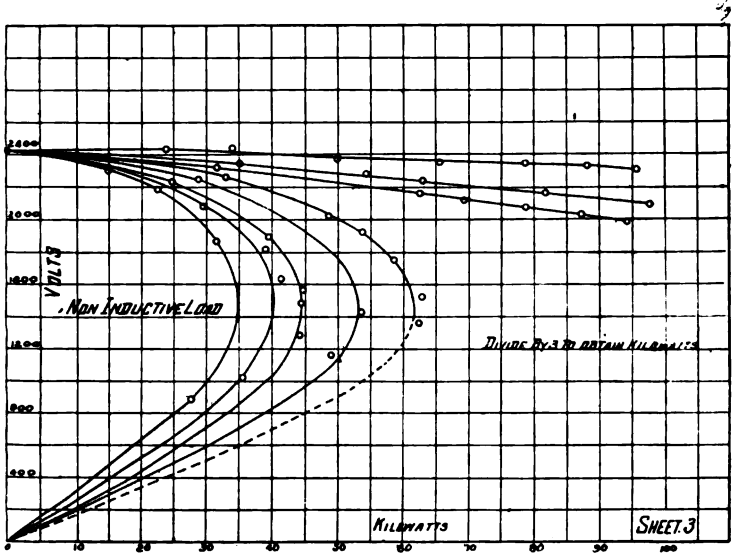
The watt curve in Sheet 4 all exhibit a grea
the corresponding non-inductive curve of Sheet
more pronounced than in the current curves, as
expected. They do not exhibit the same sym
bend round towards the axis of zero watts as
This may be explained by the fact that the "ob
the external load being constant, the energy
directly proportional to but one variable—the squ
—consequently, although the terminal voltage
may be much less, due to a greater load produce

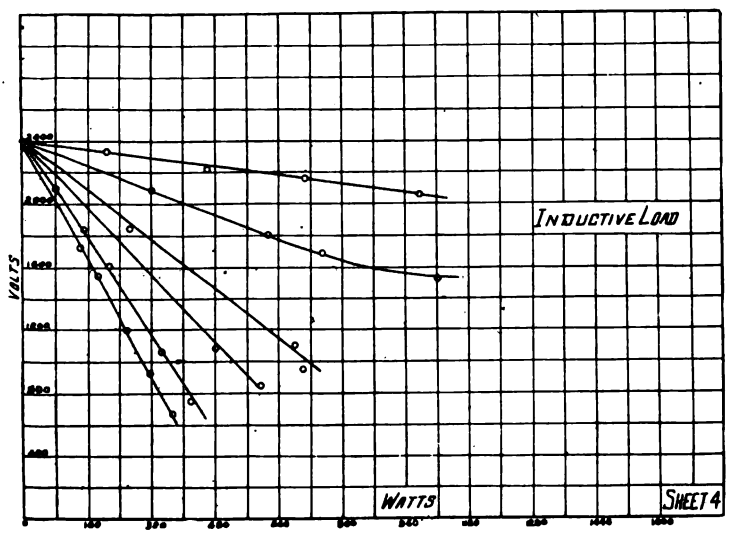
the external inductance load, the resultant increase of current causes a greater expenditure of energy in the form of C^2R. The apparent irregularity of the upper curves may be due in part to the actually small, but proportionally large, increase of resistance of the coils of the variable inductance due to their excessive heating.

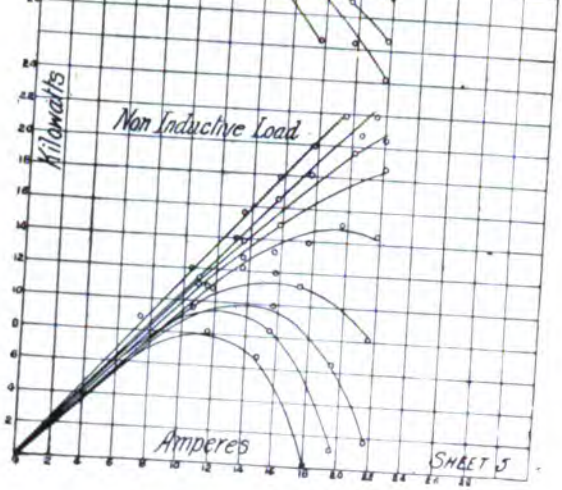
The two curves of Sheet 6, when compared with the corresponding ones of Sheet 5, show the same general difference as did the current and watt curves. On account of the low precision of the results, and the nearness together of the separate curves, the two extreme positions only were plotted, the intermediate curves being either indicated or omitted. The upper set of curves shows the extremely low power factors obtained, and the curious way in which they varied as compared with those of Sheet 5. The lower set shows how the energy input of the transformer increased with increase of current; almost the reverse of the case on Sheet 5,—the reason, of course, being that mentioned in the case of the watt curves, namely, that the C_2R load increased as the total of inductance load decreased and the lag became less.

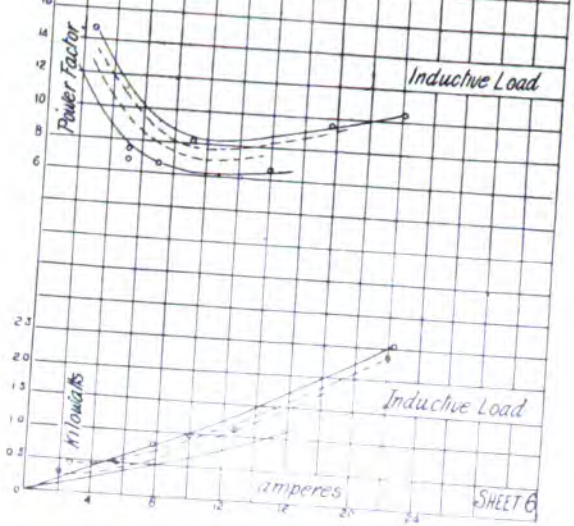

NON INDUCTIVE LOAD
PRELIMINARY RUN
AMPERES

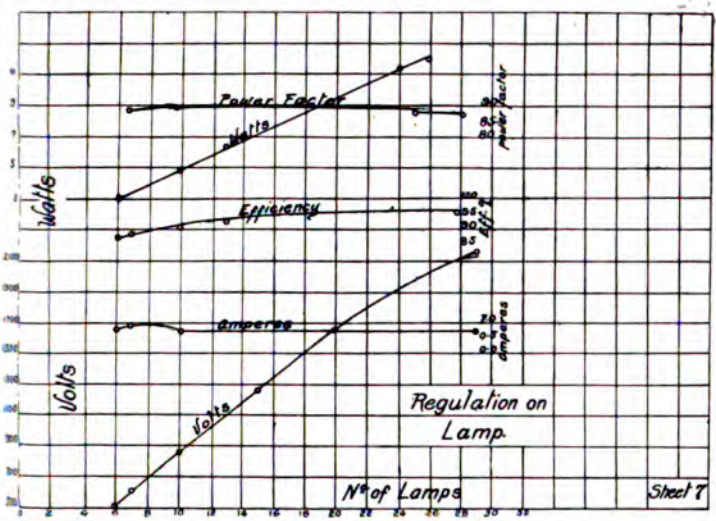

AMPERES

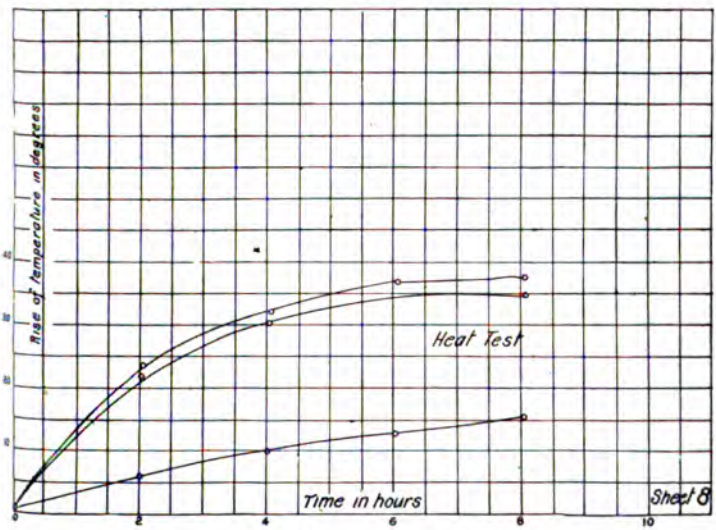

VOLTS
NON INDUCTIVE LOAD
DIVIDE BY 3 TO OBTAIN KILOWATTS
KILOWATTS
SHEET 3

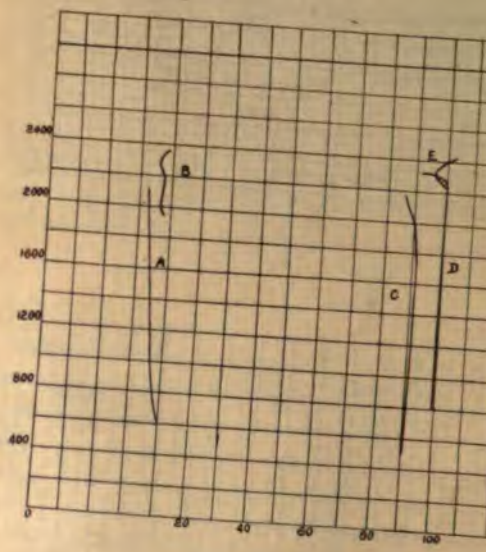

VOLTS
INDUCTIVE LOAD
WATTS
SHEET 4


Kilowatts
Non Inductive Load
Amperes
SHEET 5


Power Factor
Inductive Load
Kilowatts
Inductive Load
amperes
SHEET 6


Power Factor
Watts
Efficiency
Amperes
Volts
Regulation on
Lamp.
Nº of Lamps
Sheet 7


Rise of temperature in degrees
Heat Test
Time in hours
Sheet 8


2400
2000
1600
1200
800
400
0
20
40
60
80
100
A
B
C
D
E

DOMI
34
32
76

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VOL. XIX. 1905. PART II.

TRANSACTIONS

of the

Canadian Society of Civil Engineers

OCTOBER TO DECEMBER

1905

Montreal:
PRINTED FOR THE SOCIETY
AT THE WITNESS PRESS
1906

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INSTRUCTIONS FOR PREPARING PAPERS, ETC.

In writing papers, or discussions on papers, the use of the first person should be avoided.

They should be legibly written on foolscap paper, on one side only, with a margin on the left side.

Illustrations, when necessary, should be drawn on the dull side of tracing linen to as small a scale as is consistent with distinctness. They should not be more than ten inches in height and *in no case* should any one figure exceed this height. Black ink only should be used, and all lines, lettering, etc., must be clear and distinct.

When necessary to illustrate a paper for reading, diagrams must be furnished. These must be bold, distinct and clearly visible in detail for a distance of thirty feet.

Papers which have been read before other Societies, or have been published, cannot be read at meetings of this Society.

All communications must be forwarded to the Secretary of the Society from whom any further information may be obtained.

The attention of Members is called to By-Laws 46 and 47.

The Society will not hold itself responsible for any statements or opinions which may be advanced in the following pages.

"The papers shall be the property of the Society, and no publication of any papers or discussion shall be made except by the Society or with permission of Council."—By-Law No. 47.

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BUSINESS MEETING.

The session was opened by a business meeting, held on Thursday, October 12th, for the opening of ballots for the election of members, Mr. J. A. Jamieson in the chair. Messrs. Jamieson, McNab, Heckman, Legrand, and Jost having been appointed scrutineers, declared the following elected:

MEMBERS.

F. A. Bowman.
J. J. Collins.
G. W. Catt.
W. Cross.
A. C. Joly de Lotbinière.
C. E. Perry.
T. K. Thomson.

ASSOCIATE MEMBERS.

F. W. Angel.
T. A. Bown.
F. S. B. Calcott.
J. G. W. Campbell.
F. E. Courtice.
W. F. Jennison.
A. LaRocque.
W. H. Magwood.
D. Morrison.
R. S. Dahl.
J. E. A. Egleson.
A. S. Fairbanks.
H. E. Heustis.
M. G. Henniger.
C. Reaves.
C. P. Sanders.
A. T. Spencer.
W. W. Van Every.

Transferred from the class of Associate Member to the class of Member:

F. A. Creighton.
H. J. Lamb.
G. A. McCarthy.

Transferred from the class of Student to the class of Associate Member:

E. F. T. Handy.
S. B. McConnell.
J. O. O'Sullivan.
W. P. Wilgar.

ASSOCIATES.

T. Simmons.
E. Van Winkle.

STUDENTS.

A. Babin.
A. H. W. Birch.
J. Bonin.
C. J. Bruce.
M. M. Campbell.
H. B. Cressman.
A. R. Crookshank.
S. Dingwall.
A. Dick.
A. Ferguson.
L. R. Gransaull.
J. H. Grice.
H. M. Haughton.
F. H. Kitto.
H. F. McDonald.
J. A. C. MacDougall.
C. C. Malloch.
J. R. Morrison.
J. P. Menard.
R. H. Mulock.
P. J. B. O'Sullivan.
A. A. Paradis.
S. J. Tuck.
J. de Stein.

ELECTRICAL SECTION.

President—R. B. Owens.
Vice-President—M. J. Butler.

A meeting of the Electrical Section was held Thursday, November 2nd, 1905, Dr. R. B. Owens in the chair. The following papers were read:

PAPER No. 230.

AN ELECTRIC ACCELEROMETER.

By R. B. Owens, M. Can. Soc. C. E.

The advent of the electric motor as a competitor of the steam engine, especially in the traction field, has given rise to certain acceleration problems unfamiliar to engineers of a generation ago. At a time when the train mile was a satisfactory unit in which to reckon haulage costs, there was little occasion to bother with acceleration. Now, however, when neither the train mile, car mile, nor ton mile suffice, even when coupled with a speed factor as a basis of estimation and analysis, now when to maintain certain schedules more energy is expended in accelerating than in overcoming frictional and grade resistances, a simple, accurate, and reliable means of measuring acceleration is urgently demanded,—a means at least comparable in simplicity and accuracy with those employed in the measuring of the quantities of which it is the second and first differential with respect to time. The measurement of length is familiar to all. Of practical methods of measuring velocity or speed, at least of machines, one of the most satisfactory, if not the most satisfactory, involves the use of a suitable constantly excited or permanent magnet dynamo mechanically driven by the piece whose velocity is to be measured, and electrically connected through an ammeter to a circuit of constant co-efficients as shown in Fig. 1.

S is the shaft whose velocity is to be measured. C is a mechanical coupler. A is the armature of a small permanent magnet or constantly excited continuous current dynamo wound so as to have a negligible reaction within the limits of its use. R is a variable non-inductive resistance and I is a zero centre d. c. ammeter. The reading of I will be proportional to the speed of S and by adjusting R, can be calibrated in the revolutions per minute, feet per second, or miles per hour as desired. As the current through

I is proportional to speed, it is only necessary to determine the rate at which the current varies in order to have a measure of acceleration. This is simply and easily done by inserting in the circuit with I a transformer T with its secondary connected, for purposes of adjustment, through a non-inductive resistance R_1, to a zero centre d. c. voltmeter V (see fig. 2). The reading of the voltmeter V will then be proportional to the acceleration, positive or negative, of the shaft S.

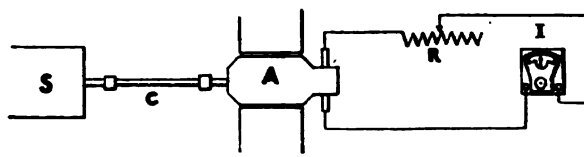


FIG. 1.

Substituting recording instruments for the indicating ones shown, we have a recording speed indicator and a recording accelerometer. The transformer must have a straight line saturation curve and a large transformation ratio as the secondary induced voltage is necessarily small and the voltmeter V must also be sensitive. The calibration of the ammeter as a speed indicator is effected by driving the armature A at different constant speeds as shown by ammeter reading, and taking the revolutions in a given time by means of a revolution counter and stop watch. The calibration of the voltmeter as an accelerometer is best done by driving the armature A by a separately and constantly excited motor having applied to its armature, preferably of small momentum, a voltage varying approximately as a linear function of time. With proper manipulation of apparatus the ammeter readings plotted against time will be a straight line whose slope will be constant and equal to the acceleration and to the constant reading of the voltmeter to within a constant.

In some tests made in the writer's laboratory not long ago. A (see again fig. 2) was the armature of a small low voltage separately excited d. c. generator; S the shaft of a 3 h.p., separately excited

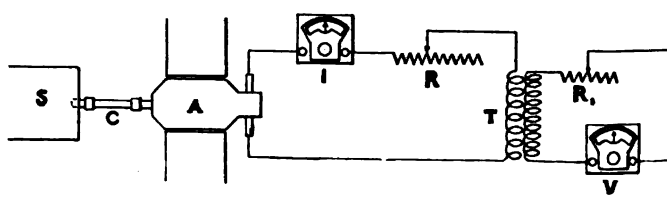


FIG. 2.

d. c. motor to whose armature by a potentiometer arrangement a steadily increasing or decreasing voltage could be applied; I and V Weston ammeter and millivoltmeter and T a small lighting transformer with a transformation ratio of 20. Excellent results were obtained, speed and acceleration being read to exactly the same degree of accuracy that Weston d. c. ammeters and voltmeters are capable of. With recording instruments substituted, this would seem to meet every requirement of a practical apparatus for the measurement and recording of velocity and acceleration in railway work, both steam and electric, and is applicable, of course, in many other connections.

PAPER No. 231.

OSCILLOGRAPHIC RESEARCHES ON SURGING IN HIGH TENSION LINES. BY C. DAVID.

Abstracted with Introduction by L. A. HERDT, A.M. Can. Soc. C.E

When a current is flowing through a circuit containing inductance, energy is stored in its magnetic field, the amount of energy being equal to one-half the product of the inductance into the square of the current. If the E.M.F. producing the current be suddenly removed, this energy will dissipate in heat. If the circuit be suddenly opened, the rate of the dissipation of the stored energy will be great and consequently the E.M.F. will be very high. In addition to magnetic reactance, a circuit will have more or less electrostatic capacity, that is, a certain quantity of electricity is required to charge the line. This energy is stored and will be restored again when the line is discharged. The amount of energy stored is one-half the product of the electrostatic capacity of the line into the square of the voltage. Energy is therefore stored in two ways in a system of electrical conductors.

A change of circuit condition taking place, as the switching on or off of an additional line, the opening of a circuit with or without load, sudden changes of load, etc., may cause violent and sudden alterations in the energy condition of the circuit, setting up electric oscillations which are liable to give rise to destructive voltages extending over the whole system and causing breakdowns of insulation.

When a transmission line is switched on busbars maintained at constant potential, the line may be considered as a condenser with inductance and resistance in series. According to theory (Steinmetz—Transactions of A.I.E.E., 1901, Oscillations in High Potential Transmission Lines), the maximum value of the oscillating E.M.F. induced is equal to the impressed E.M.F. producing the surging; that is, when a line is connected to a source of E.M.F. the potential may rise to double potential and will then oscillate between this value and zero with continually diminishing amplitude. The amplitude of the oscillations set up depends on the point of the impressed E. M. F. wave at which the circuit switch is closed. Also the frequency of the oscillations set up is independent of the impressed frequency but depends on the line constant.

Theoretically, then, the maximum rise of potential which can occur in connecting a transmission line to the generator busbars when the reflected surge adds to the impressed E.M.F. is 100%.

In practice it will be seldom that the switching takes place when the impressed E.M.F. is at its maximum.

When opening a high tension circuit, the rise of potential will depend upon how suddenly the current is interrupted, and how much magnetic energy is stored in the circuit. This matter is treated by Steinmetz in the paper above referred to, and it is there stated that "The electric oscillations produced by opening a transmission line under load may reach destructive voltages, and the oscillations caused by interrupting a short circuit are liable to reach voltages far beyond the strength of any insulation." Also that "the voltages produced by the oscillations in opening a transmission line under load or under short circuit are moderate if the opening of the circuit occurs at a certain point of the E.M.F. wave. This point approximately coincides with the moment of zero current."

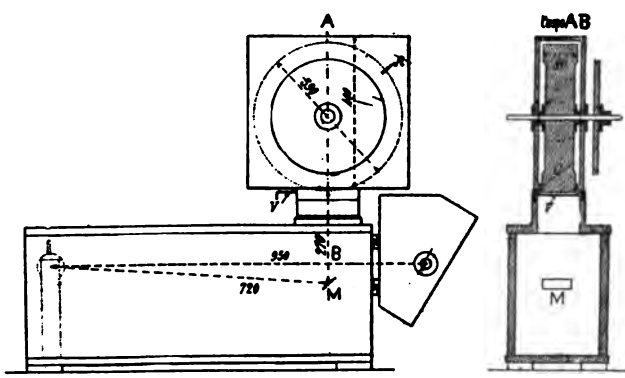


FIG. 1.

Electrical oscillations may be caused in electric circuits by resonance. In very few cases, however, in actual transmission and distributing circuits, can the rise of potential be attributed to this cause.

Among many papers dealing with the subject of surges on transmission lines, the only one so far giving the result of actual experiments recently appeared in the transactions of the Société Internationale des Electriciens. The paper is by Mr. Charles David, on Oscillographic Researches made by the Central Electrical Laboratory, Paris, on the High Tension Circuit of the Mediterranean Coast Power Co. This paper is very valuable, and the following abstract should prove interesting to the members of the Electrical Section of the Society.

The instantaneous values of E.M.F. and current were obtained by means of a Blondel-Charpentier oscillograph.

In the ordinary form of oscillographs, the images are obtained on a photographic plate 3.5" by 4.5". It was advisable to arrange

some means by which the records would be taken for a time sufficient to include conditions not only during the period of surging but for the time before and after.

Instead of the ordinary plate, a film 3.5″ wide by 4.5 feet long was wound on a wooden cylinder (Fig. 1), placed in a closed box with a shutter and arranged so that the images on the galvanometer mirrors could be thrown on the film. This drum was rotated by a small motor, so that the width of a period length as shown on the film could be altered by speeding or slowing the motor. It was thus possible to obtain a large number of periods on one film.

The transmission lines experimented upon are shown in Fig. 1A.

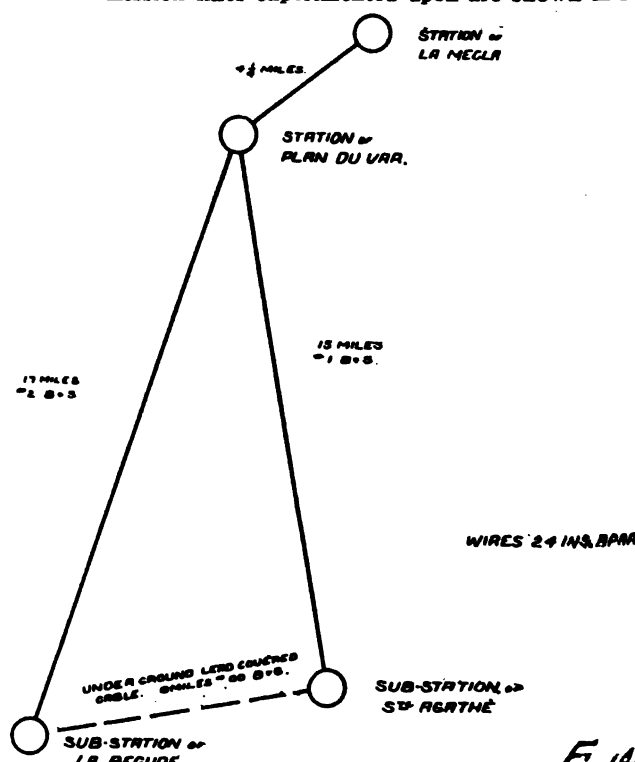


Fig. 1A

The two stations of Plan du Var and La Mecla operate in parallel. These stations are 4½ miles apart. The line joining them is overhead, 3 phase, 3 conductors, 24″ apart, No. 1, B. & S. copper wires. From station of Plan du Var two overhead transmission lines, 17 and 15 miles long, go respectively to sub-stations at La Bagude and Ste. Agathe. The line to La Begude is made

up of three conductors, No. 2, B. & S., 24″ apart, and that to Ste. Agathe of No. 1, B. & S. conductors same distance apart.

The sub-stations at La Begude and Ste. Agathe are connected by an underground 3 conductor lead-covered cable 8 miles long, No. 00, B. & S. conductors.

Capacity in m.f. between one conductor and the other two connected to the lead covering, 0.825 per 1,000 feet.

Capacity in m.f. between the three conductors joined together and the lead covering, 0.825 per 1,000 feet.

It was thus possible to experiment with a circuit forming a loop of a total perimeter of 40 miles—32 miles of which were overhead, the remaining eight miles underground, the underground part about midway along the loop.

A 3 phase 600 K.V.A.—25 Cycle—11,000 volt alternator, driven by a 900 h.p. horizontal turbine, provided the electric power.

The switchboard in the station was equipped with high tension oil switches, and three pole air knife switches were also provided.

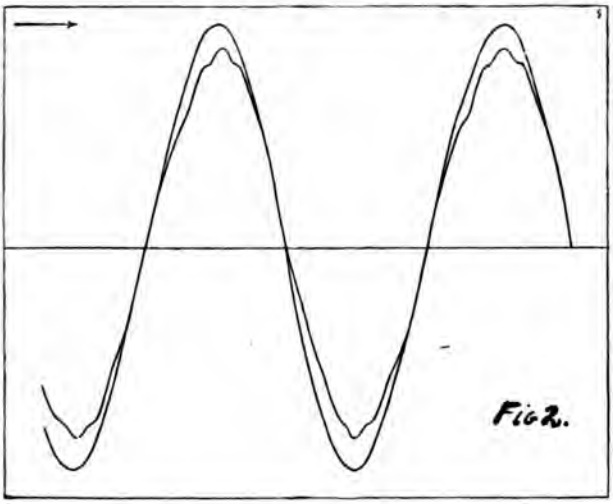
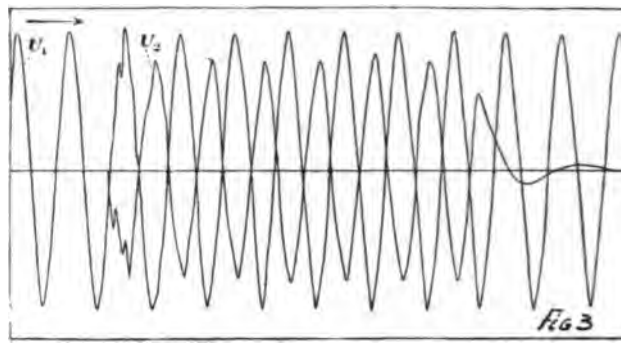


Fig. 2 shows the no load E.M.F. wave of the alternator, the machine giving an effective voltage of 7,000 at a frequency of 25. The sinusoidal curve is also shown.

In this particular E. M. F. wave. the effect of the fifth and seventh harmonics are the only ones noticed and they are quite small, the fifth being less than 2% of the value of the fundamental one.

The first experiments consisted in making and breaking with an air switch the charging current at the sending end of the line,

the charging current being approximately five amperes at 8,900 volts. The 40-mile circuit was unloaded but for a few transformers with open circuit secondaries which were left accidentally on the line.



In Fig. 3 U_1 is the E.M.F. wave across one phase at the generator, U_2 the voltage at the end of the line. Waves U_1 and U_2 have been shown in opposition of phase, that is, U_2 is displaced by 180° to show the two curves more distinctly.

The line is shown to have been switched on the busbars when the impressed E.M.F. is changing sign, and, as would be expected, the oscillations produced are very small. The oscillations cease in the first half period after the make. When the line is opened there are no oscillations on U_1, but the wave U_2 shows at the rupture a damped oscillation of large period.

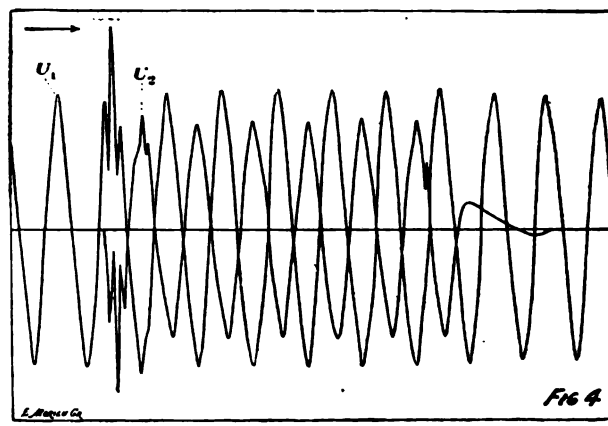


Fig. 4 shows the line switched on at the moment when the impressed E.M.F. is near one-fourth period.

At first the impressed E.M.F. is suddenly reduced, but further

a rise of potential takes place, giving a 50% increase of impressed pressure. A rise is also shown on wave U_2. The oscillations cease in the first period after the make. Here, again, there are no oscillations in the impressed E.M.F. waves when the circuit is opened. but U_2 shows a momentary surge.

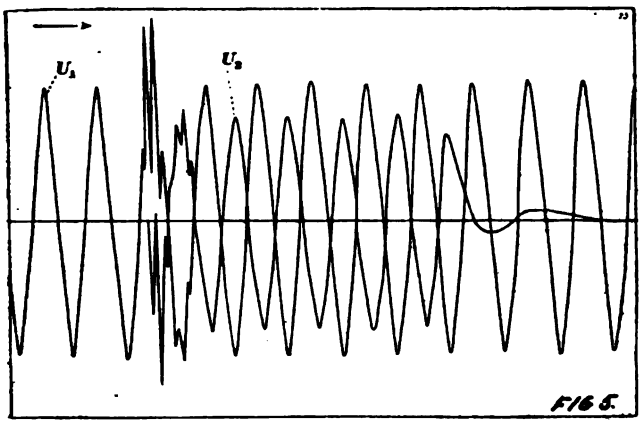


FIG 5.

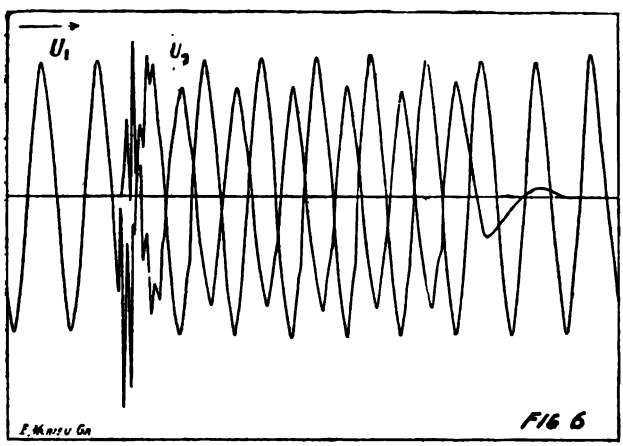


FIG 6

Figs. 5, 6 and 7 show the conditions of U_1 and U_2 when the line was switched on at the moment when the impressed E.M.F. is at or near one-third, one-half, and two-third period. The surges on both U_1 and U_2 are well shown and are quite large. The rise of potential, however, did not in any one of a large number of

experiments exceed 55%. The oscillations take place in one period after the make of the switch. When the switch was opened the voltage never rose, but in all cases the wave U_2 shows a much longer period and is damped out in a single oscillation.

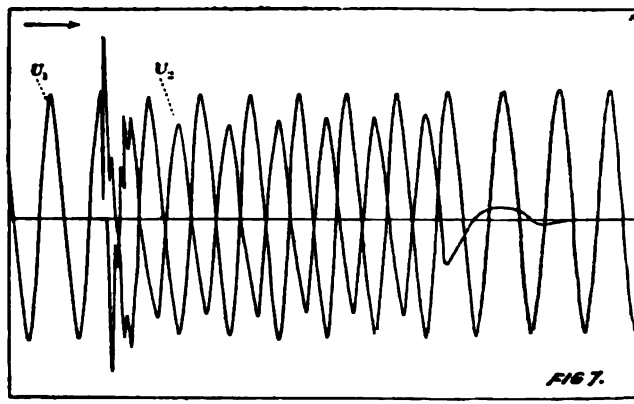


FIG 7.

The percentage of the number of times in which surging appeared to the total make and break equalled 66%.

Records taken on the unloaded line, when operated with an oil switch in place of the air switch, do not differ very much from those just shown.

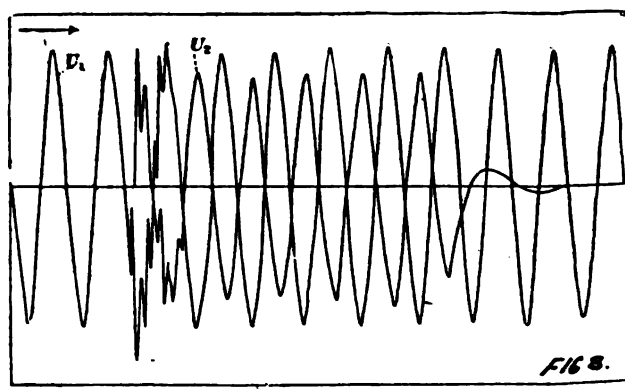
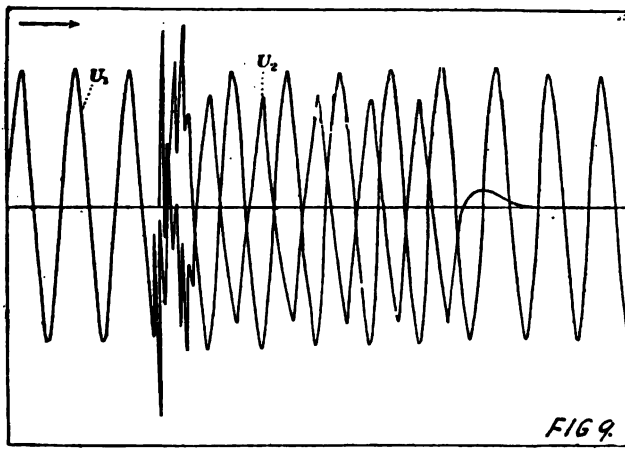


FIG 8.

Fig. 8 shows the value of U_1 and U_2, the unloaded line switched in with an oil switch at the moment when the impressed E.M.F. is near one-half period. The rise of potential for U_2, which for the air switch (Fig. 6), was considerable, 50% as near as can be

judged, is only about half of that amount. U_2, although it shows considerable oscillations, shows no rise of potential.

Fig. 9 is for a similar load, but the time of switching is near the maximum value of U_1. The rise of potential is 60% for U_1 and 58% for U_2. This is somewhat greater than that obtained with the air switch under similar conditions.



At the opening of the circuit there are no oscillations or rise of potential in U_1 as for U_2. A damped oscillation of long period takes place in every case.

In twelve different experiments, the rise of voltage for U_1 and U_2 is as follows (line switched in):—

U_1 (E.M.F. at busbars)	one	rise of	potential	64%
	two	"	"	60%
	one	"	"	50%
	three	"	"	25%
	one	"	"	18%
	two	"	"	10%

U_2 (difference of potential at end of line):

one	rise of	potential	67%
two	"	"	64%
one	"	"	58%
two	"	"	30%
one	"	"	25%
two	"	"	17%
one	"	"	8%

So far as these experiments go, there is not very much differ-

ence whether an oil or an air switch is used. Whenever the switching in takes place when the impressed E.M.F. is near zero, the rise of potential will be very small. At other times the rise of potential will be considerable and violent oscillations will be set up, disappearing in one period. At the break no rise of potential under any conditions has been noticed.

EXPERIMENTS WITH NON-INDUCTIVE LOAD, OIL SWITCH.

Oscillographic records are given for: first, the switch placed between the generator busbars and the line; second, switch placed

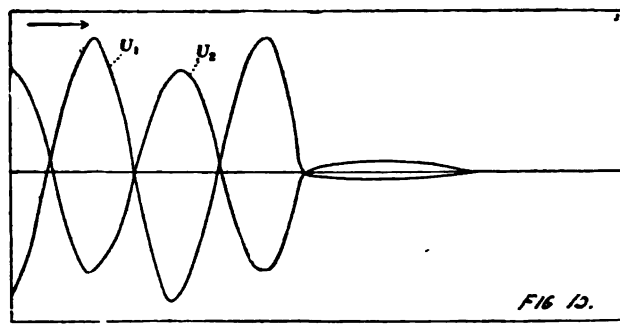


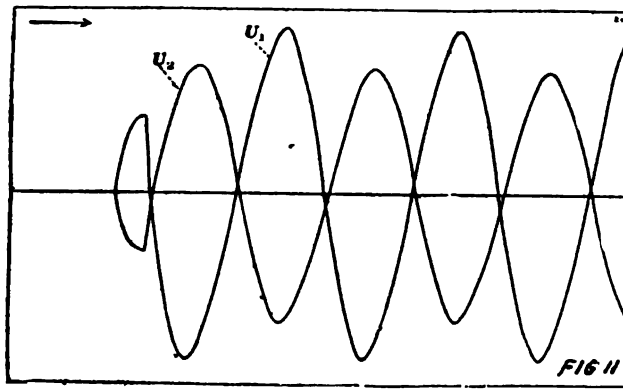
FIG 13.

between the line and the load. A three phase water rheostat was placed at the end of the line as a load.

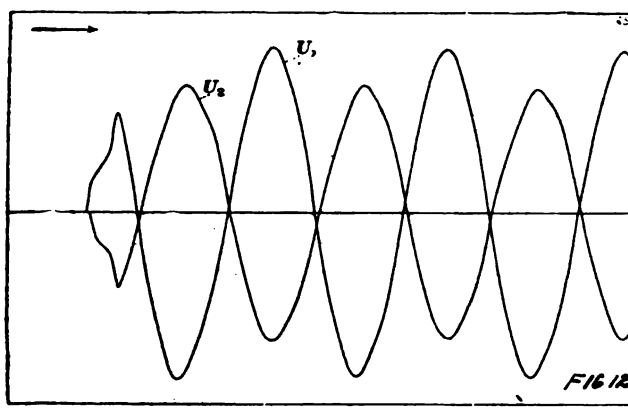
The experiments under load were carried out in the following manner. The alternator was loaded through the 40-mile line on the water rheostat. The switch was then opened for one-half second and then closed. The load was adjusted to 22 amperes, a voltmeter on the line side of the switch reading U_1 (7,200 volts on one phase) and a voltmeter placed on the rheostat reading U_2 (6,200 volts).

SWITCH PLACED BETWEEN GENERATOR BUSBAR AND LINE, OPENING OF CIRCUIT.

Fig. 10. The opening of the switch is shown to have taken place when U_1 is zero. No rise of potential. Other records show similar result. The break is always shown to take place at zero value of impressed E.M.F. Mr. David is uncertain as to whether this is due to the oil switch or pure hazard.



In Figs. 11 and 12, waves U_1 and U_2 are shown when the switch is closed. There is no surging or rise of potential. The regime is steady after the first period following the close of the circuit.



HIGH TENSION OIL SWITCH PLACED AT END OF LINE.

The oil switch was placed between the receiving end of the line and the rheostat, so that the alternator was kept on the line when the load was switched off.

SWITCHING IN.

In Fig. 13, U_1 and U_2 are respectively the E.M.F. of the generator and the difference of potential on the line side of the switch (U_1=7,300 volts, U_2=6,100 volts, the current 26.5 amperes). Oscillations are shown on U_1 and U_2, but without rise of potential.

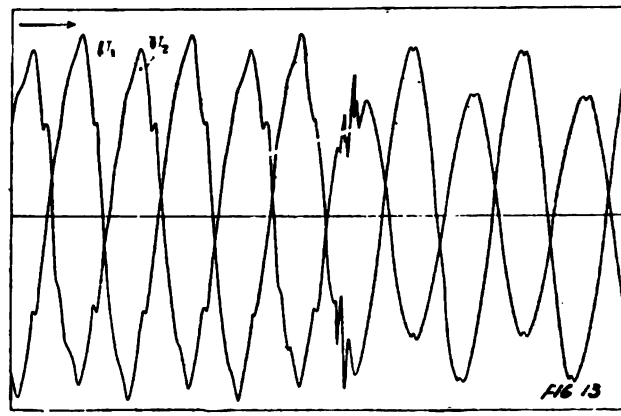
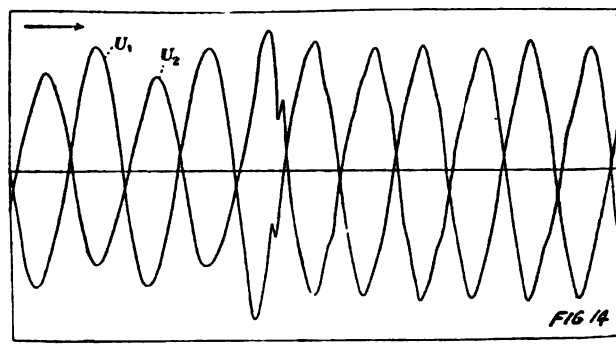


Fig. 14 gives values of U_1 and U_2 when the switch is opened. The rise of voltage on U_1 is 24% and 18% for U_2. Oscillations take place in the time of the period corresponding to the unswitching. In the course of a large number of experiments under similar conditions of load no rise of potential ever took place at the switching



in. At the unswitching, however, the increase lies between 15% and 24%. The percentage rise of potential is usually greater at the sending than at the receiving end.

AIR SWITCH.

Experiments were carried on with an air switch, this switch being of special make, allowing the arc made at the break to rise between copper horns, increasing the length of the arc until it broke. The records show that the rise of potential with this switch is considerably greater than with the oil switch under similar conditions of load and that the oscillations are kept up for at least two periods after the opening of the circuit.

EXPERIMENTS WITH AN UNDERGROUND CIRCUIT.

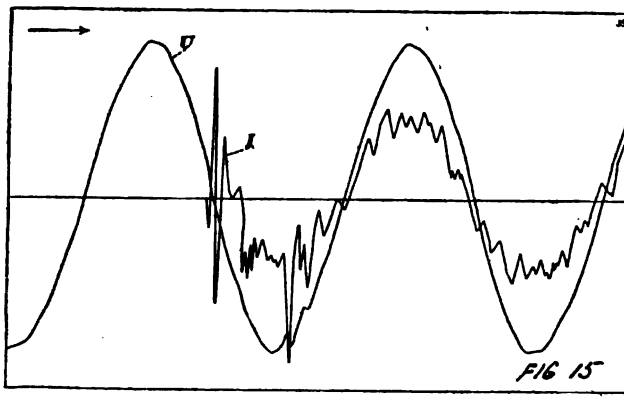
The cable experimented with, is a three conductor lead-covered cable, four miles long.

The cable unloaded was switched on the busbars through an oil switch, and records of E.M.F. and current are shown in Fig. 15.

The busbar voltage was 9,700. The current value is not given but could not be more than a few amperes.

In Fig. 15, U the E.M.F. wave shows little oscillations, not so with the current wave I. Rapid oscillations take place during the first half period corresponding to the closing of the switch.

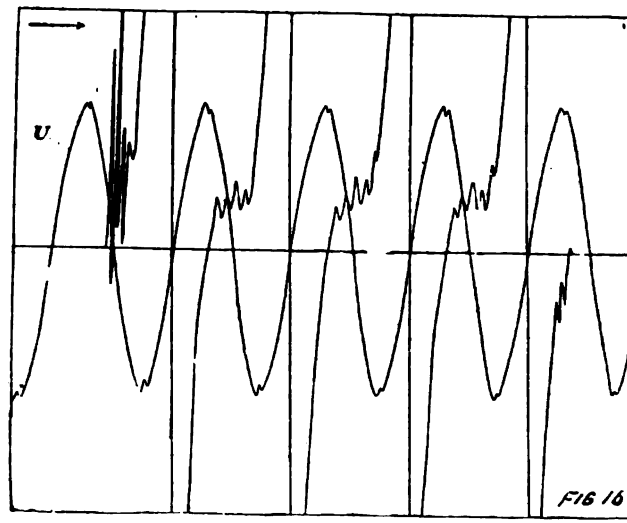
A 200 kilo-volt-ampere transformer with secondary winding open was then connected to the end of the cable.



Watt transformer input 4,500; applied voltage 9,600; the current is not given.

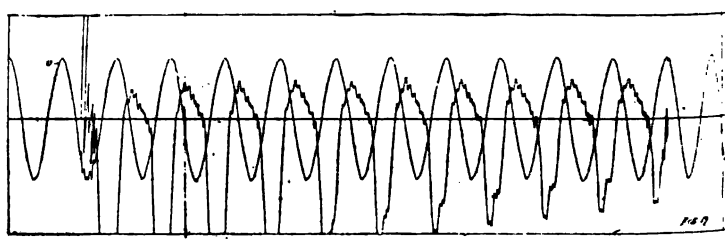
Fig. 16 shows cable switched on when the impressed E.M.F. is about changing sign. The E.M.F. wave shows no oscillations. The current wave shows violent ones. The maximum values of the current exceeded the width of the film and are not recorded on this plate. The negative and positive waves are dissimilar and the distances between the zero values are unequal. The switch was opened after an interval of four periods, the current had not then taken its normal value.

Fig. 17 shows E.M.F. and current waves for a similar test, but the switch closed at one-third period. Small oscillations are shown on the E.M.F. wave. The current wave is again very erratic, starting with a large rise of current, followed by a series of rapid oscillations. The circuit was opened at the end of the eleventh period,



but the current had not taken its normal value. The effect of the unswitching is shown by a small oscillation of the E.M.F. wave.

A number of experiments were taken and show similar



results. In all cases it is shown that the E.M.F. wave suffered very small disturbance at the closing or opening of the circuit, but the current waves show violent oscillations.

These experiments are not sufficient to arrive at definite conclusions, but they show that there is a danger of overvoltage when a transmission line is thrown on generator busbars except when the switching in is done at or near the moment when the impressed E.M.F. is zero; there is no danger of overvoltage when the line is switched off, the charging current being usually small.

There is danger of overvoltage when a loaded line is switched off the high tension busbars and the oil switch is likely to prove less dangerous than the air switch.

MECHANICAL SECTION.

President—R. J. DURLEY.
Vice-President—G. J. DESBARATS.

A meeting was held on Thursday, November 16th, Mr. R. J. Durley in the chair. Mr. Harrington read the following paper:

PAPER No. 232.

THE WHARF CRANES OF THE PENNSYLVANIA RAILROAD COMPANY AT GREENVILLE, N.J.

By JOHN LYLE HARRINGTON, M. Can. Soc. C. E.

The great industrial development of the last century was accompanied and largely made possible by co-ordinate growth in the facilities for both foreign and domestic transportation. Within that period the railway became the most important single factor in the material life of all progressive nations, and the steamship relegated to a secondary place the sailing craft which had been for all the preceding centuries substantially the only means of carrying on the foreign or domestic commerce.

The traffic carried by the railways and the merchant-marine of the world has assumed almost incomprehensible proportions, but the development of the means for transferring goods from one great carrier to the other has not kept pace with the demand. The mast and gaff, operated by the ship's winches, and the hand truck still remain the chief means for handling package freight, though the greater steamship lines have very recently equipped their wharves with electric hoists to operate the mast and gaff.

The handling of iron ores, however, has received the attention of many of our ablest engineers during the last third of a century, and the traffic in iron ore now existent upon the great lakes is only made possible by the improved facilities for removing the ore from the vessels and delivering it to railway cars cheaply and with dispatch.

The handling of coal, especially in the seaboard cities, has also received the attention of specialists, and the machinery for this work has reached a high state of development.

This rapid and economical handling of ores, fuel, and flux has greatly reduced the cost of iron and steel, and thus exerted incalculable influence upon the world's industrial growth.

Cranes for handling package freight have been sporadically developed, here and there, for handling very heavy loads. The most notable of these are the cranes used by the great navies for the trans-shipment of heavy guns. But the greater portion of the package freight is still handled by comparatively primitive means The cost of trans-shipment is great, and the earning power of vessels and cars is considerably reduced because they are idle during the time required for loading and unloading cargo.

Both the railway and the steamship companies are rapidly reaching the conclusion that they must make the necessary expenditure for freight-handling machinery, if the work is to be done economically and quickly. About two years since, when the Pennsylvania Railroad Company began the construction of its new freight terminus in the New York harbour at Greenville, N.J., they invited various engineers and builders of prominence to submit designs for cranes, to be operated by electricity and to handle freight, both bulk and package, between the railway cars and the vessels.

In response numerous carefully thought out designs were submitted, and the engineers of the various companies tendering exposed very fully the methods of operation and construction proposed and their advantages. The Railroad Company's engineers made a minute and careful examination of these plans, visited and examined in operation various installations of hoisting machinery employing the principles embodied in the designs offered, and made a report which resulted in the selection and purchase of the three cranes described below.

By the initial arrangement there were to have been two cranes of one type designed primarily to handle loose freight, such as coal, broken stone, sulphur, and iron ore, in bulk, the third crane being of larger capacity and especially designed to handle heavy package freight; upon further study of the situation, however, the plan was modified so as to combine in one type of crane the more desirable features of both.

The cranes, as constructed, embody the best thought of the manufacturers' engineers, ably aided by the advice and suggestions of the engineers of the Pennsylvania Railroad Company, and, it is thought, represent the most advanced type of construction yet developed for the purpose.

GENERAL DESCRIPTION.

The illustrations presented herewith expose the principal features of the cranes, but there are many details of large importance

FIG. 1

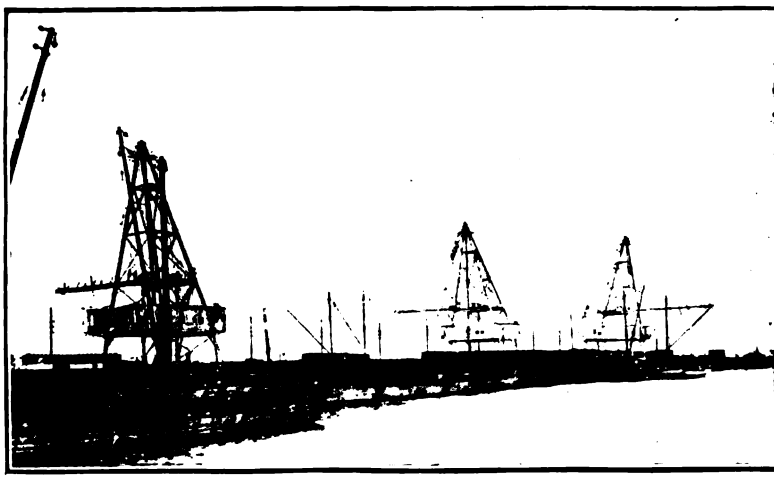


FIG. 2

FIG. 3

FIG. 4

in the operation of the machinery, which for lack of space must be left untouched.

Fig. No. 1 affords a general view of the three cranes in position upon the pier, and the railway tracks on which freight is delivered and received.

Fig. No. 2 shows the cranes disposed over the pier in operation and the arrangement along the centre of the pier of the poles which carry the feed wires for the crane, the telephone and the electric light wires, and the stationary electric lamps.

The pier is 120′ wide by about 1,000′ long, substantially constructed of timber, and especially designed to carry the cranes. Eight railway tracks are symmetrically disposed about the centre line throughout its length. Freight is delivered and received on the four tracks nearest the edge of the pier, while the four at the centre are reserved for switching purposes.

Each crane in working order weighs about 125 tons, the height is about 100′, the span centre to centre of crane trucks 41′, the distance between trucks longitudinally to the piers 30′, and the clear headroom beneath the cranes is 20′. The boom projects approximately 60′ beyond the pier, and the extreme working position of the truck is 52′ from the edge.

The cranes are designed to handle a normal load of ten tons of package freight at any point on the boom, and to operate a clam shell bucket of about sixty cubic feet capacity for handling the bulk freight. All of the cranes are designed for the use of an auxiliary hoist for placing slings about the loads in preparation for handling them with the main hoist, but the auxiliary hoisting engine is provided on only one crane.

Each crane is carried on four four-wheeled trucks running on two tracks of 14″ gauge. The two trucks at one end are driven, and the two at the opposite end are fitted with air brakes.

For the receipt of bulk materials which are handled by the clam shell bucket, a removable hopper is provided and so designed that it will occupy the space between the operators' houses, as shown in Fig. No. 3, and may be hoisted to position by the crane itself.

The boom is made to fold so as to clear the rigging of vessels, as shown in Fig. No. 4.

All of the engines and the air compressor are electrically operated and are situated in the rear of the engine house. The operators, however, are stationed one on either side of the crane, in the extreme fronts of the engine house. The windows are so situated that each operator always has a full view of the load and of the railway tracks. The levers for operating the friction clutches

and brakes are led to the operators' stands, where the controllers are also placed. The operator who controls the movement of the boom also controls the movement of the cranes along their tracks.

The cranes are amply provided with electric lights both for the engine room and for illuminating the pier and vessels for night operation.

Each crane is provided with a telephone for communication with the other cranes or with shore connections.

DETAILED DESCRIPTION.

The steel framework is designed and constructed in accordance with the Pennsylvania Railroad Company's specifications for railway bridges, in so far as they are applicable to a structure of this type. A very substantial and rigid floor system supports the engine house and takes up the vibrations of the machinery. The house itself is constructed of wood with a double floor in the ordinary manner. Access to the engine house and to the sheaves at the top of the tower is obtained by means of a ladder, shown in Fig. No. 3.

Each truck is composed of four standard chilled car wheels of the heaviest type, standard 5 x 9 journals, journal boxes and bearings, and a steel frame composed of heavy 15" channels, substantially braced. Two of the trucks are provided with air brakes, as shown in Fig. No. 10, the brakes being operated from the engine house. Each of the other trucks is fitted with a 25 h.p. railway type motor and cut spur reduction gearing for operating the crane on its tracks, as shown in Fig. No. 8. The driving trucks are also provided with double rail stops which are suspended from the body of the truck when the crane is in operation, but which are let down on the rails between the wheels when the crane is not in service. The large surface exposed to the wind would enable a very light breeze to move the crane along the tracks, but after a very slight movement two pair of wheels mount these stops and prevent further travel in either direction. All the trucks are articulated in two directions, hence a proper bearing on the tracks is always assured, no matter what the condition of the pier may be.

The main hoisting engine, which is illustrated in Figs. Nos. 5 and 6, is designed either to handle the package freight on a one, two, or three part rope, or to operate the clam shell bucket, for which two ropes are, of course, required. It is fitted with a solenoid brake and with an exceptionally large and efficient load brake, which absolutely prevents the load from running down in case the current should be cut off or accident should happen to the motor. A small drum attached rigidly to the shaft, as shown on the near

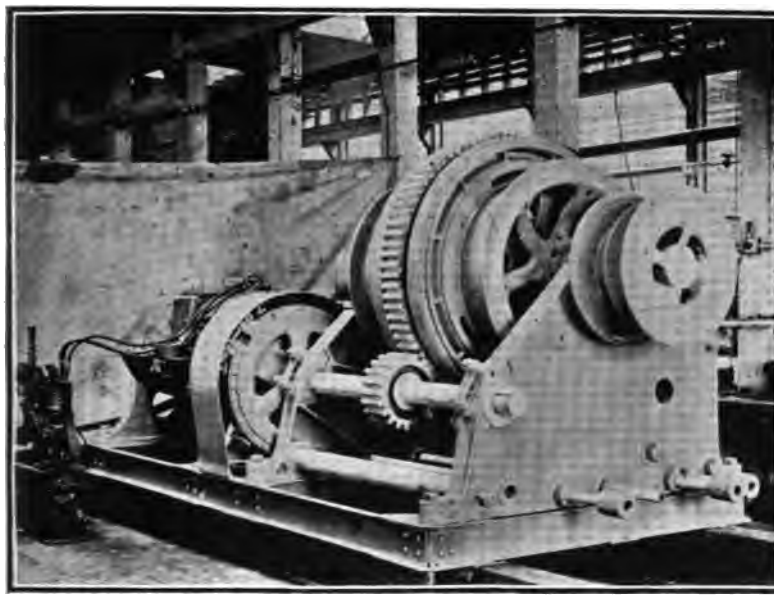


FIG. 5

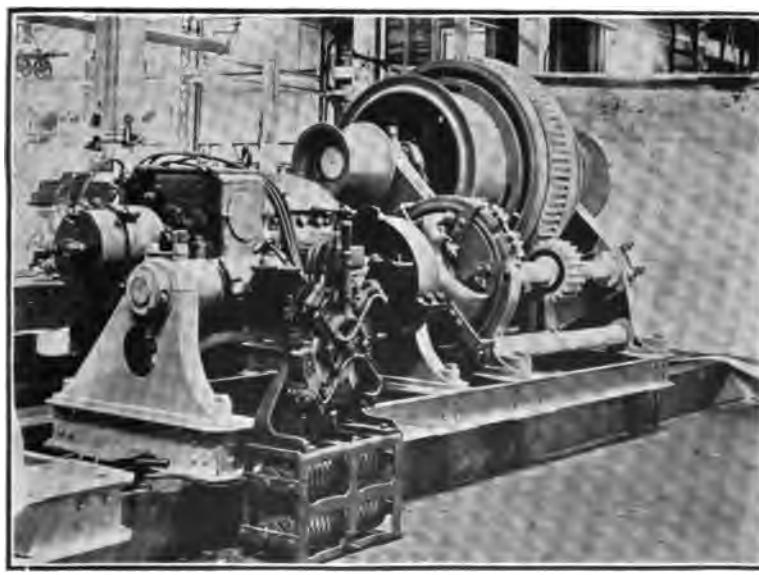


FIG. 6

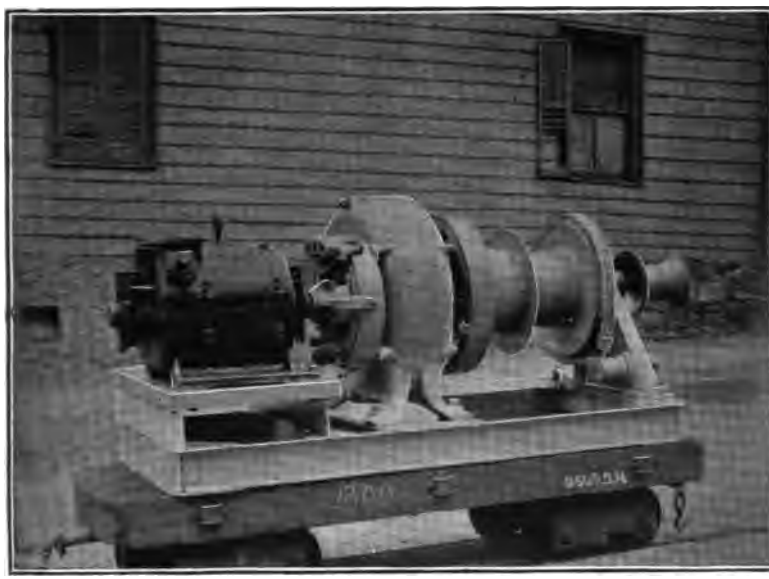


FIG. 7

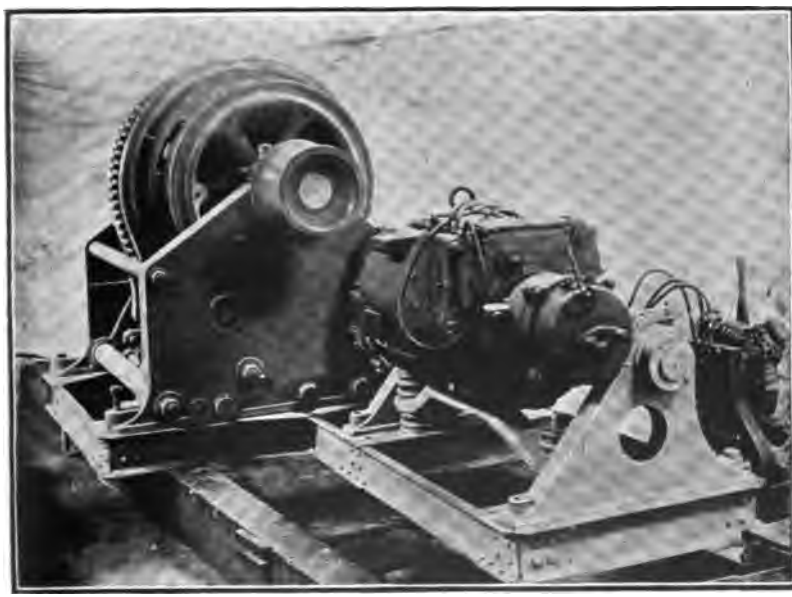


FIG. 8

end in Fig. No. 5, is used to fold the boom. Each of the main hoisting drums is fitted with a conical friction clutch and a band brake, and consequently is under full control of the operator. A 100 h.p. motor wound for 500 volts direct current and mounted on springs, much as it would be on a railway car, operates the engine.

For hoisting package freight but one rope is used. This is led from one of the drums directly over a large sheave in the head of the tower, thence over the outer of the two boom truck sheaves, around the sheave in the running block, over the inner sheave on the boom truck, and then attached by a shackle to the running block, as shown in Fig. No. 11. Obviously a single or double part rope may be used for rapid work with light loads.

When the clam shell bucket is employed the main hoisting rope is operated by one drum, and the closing rope, which also assists in the hoisting, by the second drum. These ropes also lead over the sheaves in the head of the tower, thence over the sheaves in the boom truck, and connect to the bucket.

The boom truck is fleeted outward along the boom by means of the engine shown in Fig. No. 7. The drum is divided into two parts, one of which is somewhat larger in diameter than the other. When the clam shell bucket is in use a single rope leads from each part over sheaves supported in the rear of the boom, thence over the sheaves at the outer end of the boom, shown in Fig. No. 4, thence to their connections on the boom truck. The rope attached to the larger part of the drum is connected to the outer end of the truck, and the other rope to the inner end. Thus the outer pair of wheels and sheave are drawn out more rapidly than the inner pair and sheave, and the truck spreads as it approaches the end of the boom. Longitudinal bars connect the two parts of the truck but permit this extension. This movement of the sheaves in the boom truck separates the hoisting ropes and prevents the clam shell bucket from turning and twisting the ropes as it enters or leaves the hold of the vessel, yet permits the hoisting ropes to come together as the bucket approaches the boom in its parabolic path.

When package freight is being handled, but one trolley rope is employed and the parts of the truck do not alter their relative position as they traverse the boom.

The engine is operated to draw the truck toward the end of the boom, while the horizontal component of the hoisting ropes brings the truck in toward the tower when the clutch and brake are released. The engine may, however, be operated to draw the truck to its inmost position if desired. This engine is also fitted with solenoid and load brakes. The reduction gears are enclosed in an oil-tight case, have cut teeth, and run in a bath of oil.

Fig. No. 8 illustrates the third engine employed to operate the auxiliary hoist for placing slings under the loads of package freight. The hoisting rope is led directly from the engine to a sheave in the rear of the boom, thence forward to a block suspended by a slide from the underside of one part of the boom. The rope is then led around the running block in the usual manner. This slide is moved along the boom and held in any position by a continuous rope running over sheaves at both ends of the boom and operated by the winch head on the engine. The engine is also operated by a 25 h.p. railway type motor mounted on springs. The hoisting drum is controlled by a conical friction clutch and band brake in the usual manner.

The construction and operation of the crane boom merits especial attention. It consists of two symmetrically disposed parts, each composed of an I beam and a channel well braced together. The parts are rigidly connected at the ends, but throughout the traverse of the boom truck are separated to admit the passage of the hoisting ropes. The truck runs on rails placed directly upon the I beams. As shown in Fig. No. 3 the boom extends to the extreme rear of the tower where the horizontal thrust due to the weight of the boom and the tension in the trolley ropes is carried by a heavy girder. The guy ropes always occur in pairs in order that the hoisting ropes may traverse the length of the boom between them, and they are so attached that the respective halves of the boom are balanced under load and do not twist. They are provided with turnbuckles near the head of the tower for adjustment.

The boom is hinged for vertical movement at the rear and at a point just forward of the front legs. This construction permits the boom to be folded to clear the vessel's rigging, as shown in Fig. No. 4, by means of blocks attached to the outer boom hinge and to the tower near its head and falls operated by the small drum on the main engine. The position of the outer hinge is so chosen that but slight additional weight is required to cause the boom to resume its normal position when the hoisting ropes are released. This additional weight is supplied by the boom truck which, when the boom is folded, lies in a pocket formed by bent ends of the rails on the rear of the boom, and by the forked brace at the rear, as shown in Fig. No. 4. The brace is hinged at the rear, and the centre line of its hinges is made to coincide with that of the horizontal rear boom hinge, in order that the brace and hinge may rise together without friction. The brace is so supported on the bracing of the tower that it does not follow the boom to a horizontal position, but remains about four feet above. The vertical forks at the

FIG. 9

FIG. 10

FIG. 11

end, however, always project below the boom, and, since they flare downward, guide it to a central position as it rises, though they permit its free lateral movement when the crane is in operation. The action of this brace is evident from an examination of Figs. Nos. 1 and 4. The brace prevents the boom from turning over when being folded, as it has a tendency to do, since the centre of gravity is well above the points of support. At the extreme rear the boom is hinged in two directions, so that it is free to be folded and to swing sidewise in either direction within the range permitted by the front legs of the tower.

The boom is supported entirely by the wire rope guys and on a combined vertical and horizontal hinge at the rear. This arrangement permits the boom to swing freely when a load is being lifted from a point not directly beneath it, minimizes the effect of the shock from the accidental dropping of a load, and substantially eliminates the danger of damage from collision between the masts of a vessel and the boom. Lateral guy ropes limit the horizontal movement of the boom when it reaches the opposite front leg of the tower.

The removable hopper is so designed that it may be lifted by the crane and dropped into its working position. Bulk freight may be delivered from it into cars on the track in front of the crane or the first track beneath it. This material may be weighed as delivered if desired.

A water main is carried along the entire length of the pier just beneath the floor, and at intervals hose connections just above the floor are provided. Each crane is provided with two universal nozzles, one on top of each front corner of the engine house, from which duplicate pipes lead to the middle of the strut connecting the rear trucks, where coupling is made by means of flexible hose to the couplings on the pier. Thus each crane is made a veritable fire engine.

The cranes were designated to operate on their tracks at a speed of about 180′ per minute under the greatest estimated resistance. The motors are, however, under series parallel of control and operate together at full or half speed. The resistance is normally far below the maximum, consequently the speed of operation is commonly much greater than 180′ per minute. In fact, the mobility of the cranes is astonishingly great. On this account it has, in operation, been found more advantageous to move the crane over the load and place the slings with the main hoist, than to employ the auxiliary hoist for that purpose. The leading of the hoisting ropes over the head of the tower and thence over the boom truck, which is never under full load, greatly facilitates the ease and rapidity of operation and greatly reduces any shock caused by

the slipping of a load. The suspension of the boom proves to be extremely advantageous. One of the cranes has been so violently struck by a vessel that the boom was forced to its extreme position and the tower itself twisted until some of the trucks left the tracks, but, owing to this extreme flexibility of the boom, the resultant damage was negligible.

The operation of the cranes as a whole has been eminently satisfactory to both their designers and builders and to the Railroad Company. They are large and expensive machines, but they have so thoroughly demonstrated their merits in the few months they have been in operation, that, in future, there is little doubt that similar machinery will be employed on all large wharves. The resultant economy in handling the freight and in the dispatch of vessels makes the installation of such machinery on all important wharves eminently advisable.

The cranes were designed and constructed by the C. W. Hunt Company, of New York. Although the plans were prepared under the author's direction, the design is the result of the combined work of Messrs. C. W. Hunt, C. C. King, Wm. Seaton, W. D. Stivers, and the author, ably assisted by Messrs. A. W. Gibbs, Genl. Supt. of Motive Power, his assistant, Mr. B. F. Wood, and Mr. A. S. Vogt, Mechanical Engineer, of the Pennsylvania Railroad Company.

DISCUSSION.

Professor R. J. Durley regretted that Mr. Harrington had not gone rather more into detail, and touched on such questions as the expense of operation and cost of handling material by means of the cranes described. He did not know whether any tests were made on the Greenville cranes or not, but was reminded of a paper, read at the joint meeting of the American Society of Mechanical Engineers and the English Institution of Mechanical Engineers last year at Chicago, on the Comparative Cost of Working Electric and Hydraulic Cranes at Middlesboro, Eng. These cranes were, of course, of a different type, but figures were given as to the cost of handling material, and as to the expenditure of electric energy. Similar data from Mr. Harrington would be most valuable. Prof. Durley.

In answer to a question from Mr. Goldmark, Mr. Harrington explained that there were two operators, one handling the engine which operated the boom truck, the other caring for the main hoisting engine. One man alone could not manage the simultaneous movements, especially in the handling of a clam shell bucket. With an ordinary crane, there was one less drum to handle. In operating a clam shell bucket, there were thirteen movements, so that one man was kept exceedingly busy with the hoisting engine alone. Mr. Harrington.

Mr. John Kennedy remarked that it was astonishing how two men could so exactly co-ordinate their movements as these operators did. It was very interesting, for instance, to watch the clam shell coal derricks in the Montreal harbour, which were operated in this way. The clam shells were literally thrown into the hatches of the steamer, making trajectory, which was the component of vertical and horizontal motions controlled by separate operators, and they were thrown with such accuracy that they seldom struck the sides of the hatches. Very skilful operators could sometimes make as many as six trips a minute, and nearly all could work steadily at the rate of four trips on a lift of seventy feet and a horizontal movement of nearly forty feet, each clam shell raising an average of 150 tons of soft coal per hour, inclusive of the time for cleaning out the hold. Mr. Kennedy.

The Greenville cranes had evidently been designed for the special work of transferring large lots of one kind of freight directly between the cars and the vessel without the intervention of a shed, and seemed well adapted for that purpose. They had

Mr. Kennedy mechanical movements that were unusual and greatly enhanced their value, making them, in his opinion, the most complete in the ports of this continent or Europe. As to the crane problem for handling cargoes of miscellaneous goods there were many complications. In ordinary cargoes, the consignments were packed in the hold with the main idea of fitting well. One package would come out for Chicago, the next for Ottawa, another for Winnipeg, etc., so that practically they could not go into the cars directly, consequently a shed was necessary. Customs House regulations and other considerations also involved this necessity. Goods making up out-going cargoes had to be received in such order as they might happen to arrive and had to be stored until the ship or particular hold was ready to receive them. On this continent there were practically no railway tracks between the shed and the ship, and in order to save space and distance of handling cargo, the shed was put as close to the side of the wharf as possible. This made it possible to handle the goods between the ship and the shed entirely without wharf cranes. In British and European ports the conditions were quite different. There the railway cars or trucks were small and light and easily handled. A car could be shoved along by men or horses, turned on a 12½ ft. turntable and pushed out of the way with almost as much ease as a large dray. As little as a ton or a ton and a half was accepted as a carload. The trucks were practically all open, being merely covered with tarpaulins, and therefore easily loaded from overhead cranes. These conditions had led to the placing of one track, or more commonly, two or three, or even four, between the ship and the shed, and wharf cranes were therefore a necessity for the handling of goods between the ship and the shed, and for loading and unloading cars on the space between. These were commonly light swinging cranes mounted on overhead moveable frames which straddled the railway tracks. The older cranes were nearly all hydraulic but many of the newer ones were electric. The lifting capacity was ordinarily about three tons, but in some ports as high as five tons. The conditions which governed the handling of cargoes on the two continents were therefore entirely different, growing largely out of the great difference in the railway cars, and so it came that general merchandise cargoes which were handled almost wholly by cranes on one side of the Atlantic were handled without them on the other.

The Greenville cranes were well adapted where the consignments were large and handled direct, but they would not be suitable for the ordinary general cargoes.

Mr. Harrington replied that the main purpose of the cranes was for handling large shipments, such as steel rails, lumber, etc. As an example of the saving in expense of handling by the use of machinery, at Port Tampa, Florida, a bonus was offered for quick loading and delivery of large shipments of phosphate rock. Machinery was put in by the Plant Line at that point, and the bonus earned in one year entirely paid for the installation. Mr. Harrington.

In reply to questions from Professor Durley, Mr. Harrington said that the speed for hoisting was less than with a steam engine, as there was only a 100 h.p. motor which operated the crane with full load at about 110 feet per minute. 420 feet per minute was obtained from a clam shell bucket. Considering the all round use of the towers, it was thought best not to have a faster rate. The number of trips that it was possible to make depended upon the facility with which slings could be attached and the truck could be run in and out, rather than on the direct hoisting, which was a smaller part of the work. In the majority of cases the crane must be moved and the load attached before hoisting began. A clam shell bucket made about three trips per minute, but with a directly connected steam hoist, about four trips per minute, so that the electric apparatus was somewhat slower. With regard to the difference in handling coal or ore by a crane of this type and by the ordinary jib crane, it was rather difficult to say. The Boston tower did very rapid work. There were some of these in use in Montreal and they were, of course, very numerous throughout the United States. The Parabolic Boom Hoist, also developed by the Hunt Company, required only one man to operate it and did very good work. In answer to Mr. Kennedy, Mr. Harrington said that most of the freight was loaded on open cars and the small packages which were loaded in box cars were simply swung in while suspended in the air. There were two rails to each track, 14 inch gauge. The tracks were made exceedingly narrow as the available space on the wharves was limited.

Mr. H. Goldmark asked if any estimates had been made comparing this type with the overhead superstructure or runway. Mr. Goldmark.

Mr. Harrington answered that the latter type would not be feasible on account of the rigging of the vessels. The longitudinal movement of the cranes was not obstructed by the rigging. It was necessary to move sometimes about half a car length, owing to the exposed position of the cranes. The runway would also be liable to trouble from the wind. Mr. Harrington.

Mr. H. Goldmark asked if the cranes were equipped with any means of moving the cars. Mr. Goldmark.

Mr. Harrington replied that a car could be drawn by blocks and tackle operated by a winch-head on the engine, but the crane Mr. Harrington.

could move more quickly than it could move the car, and the freight was handled so rapidly that there was always a switch engine present to switch cars. In answer to a question from Professor R. J. Durley, Mr. Harrington said that the two cranes could be worked at hatches about forty feet apart.

Mr. Goldmark.

Mr. Goldmark wished to know how many rails the crane could handle at one time, and if they had to come out endways.

Mr. Harrington.

Mr. Harrington replied that they would handle up to their capacity, and cranes were being designed which would take out a whole carload at once and load it. The rails were usually handled with two slings attached to one block, and one end of the sling was longer than the other. The booms would operate fifty-two feet from the edge of the wharf so that they could discharge over the outside of any ordinary ship to load a barge.

In conclusion, Mr. Harrington wished to point out the advantage of the trolley type of crane, especially where the ropes were at the end of the tower. Any slippage of the load produced no effect on this crane, but with the rigid type the jar was very heavy when the load surged. The flexible movement in the lateral direction was very helpful. These cranes could be operated at a low or high rate of speed by the control of the driving motors. The means for preventing the crane from running away might seem extraordinary, but serious accidents due to the wind blowing cranes along the track were by no means unusual, hence perfect means for prevention were necessary.

MINING SECTION.

President—J. B. PORTER.
Vice-President—H. C. BURCHELL.

A meeting was held Thursday, November 30th, 1905, Dr. J. B. Porter in the chair. Two papers were read by Dr. Porter and one by Mr. J. F. Robertson, as follows:

PAPER No. 233.

THE TESTING OF EXPLOSIVES USED IN ENGINEERING.

By J. B. PORTER, D.Sc., M.Can.Soc.C.E.

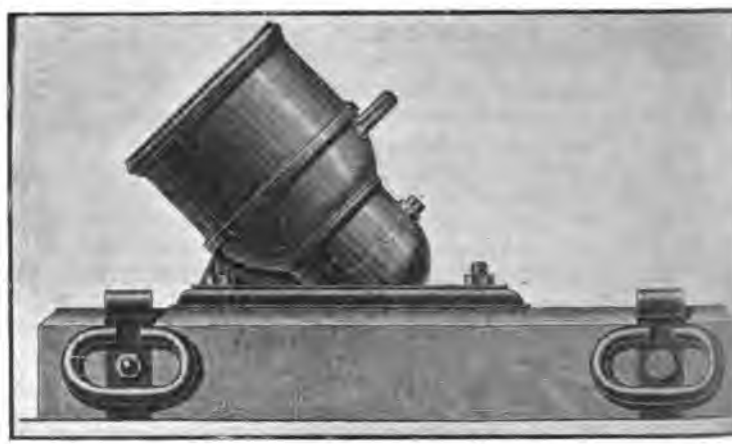
The advantages to be gained from the possession of a satisfactory method of testing and comparing explosives have long been appreciated by engineers, and during the last three centuries a very great number and variety of gauges and other devices have been invented and used, chiefly by gunnery experts. Some of these devices are admirably ingenious, and by their means very accurate investigations have been made, not only of gunpowder and similar low explosives, but even of the various high power smokeless powders, such as cordite, etc., which now form so large a part of both military and sporting ammunition.

Nearly all the work that has been done thus far has been on powders intended for ammunition for guns great and small, or for the guidance of the manufacturers of explosives; and engineers engaged in rock excavation for railway, mining, and other purposes are still supposed to be without any simple and reasonably accurate means of determining by small tests the comparative efficiency of the explosives offered them by the manufacturers.

The apparatus used for testing the explosives may be roughly classified:—

1. *Projection Machines.*—Usually small guns or mortars, using a small charge to project a comparatively heavy ball, weight, or lever. See Fig. 1. The distance the projectile is thrown is measured, or its momentum is otherwise determined, and the

result is compared with that obtained from other explosives. The earliest powder gauge known to the author was of this type, and was described by Furttenbach, in 1626. More modern mechanisms of the same general character are used to this day. The Quinan gauge illustrated in Fig. No. 2, is very largely used both in this country and abroad by manufacturers of dynamite to test their own product.



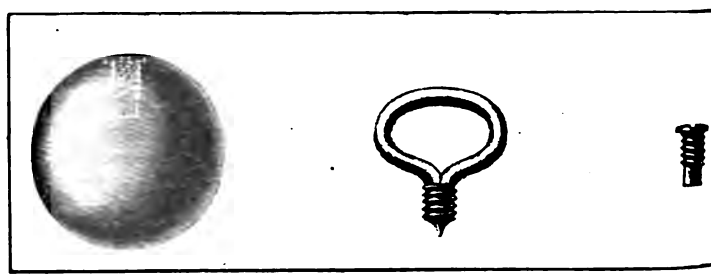


FIG. 1. Mortar for Testing Explosives.

2. *Recoil Apparatus.*—This is practically a reversal of the first type. The gun itself is mounted on a swinging arm, spring, or float, and its recoil is measured with different charges of powders, but under conditions otherwise identical. See Fig. 3.

3. *Velocity Apparatus.*—Usually applied to standard guns or cannon and so arranged that the velocity of the projectile is measured, either in the gun or after leaving it, by chronographs electrically operated. Apparatus of this type is useful not only

for testing ammunition but also for studying the laws governing the flight of projectiles, and it has proved of immense value to gunnery experts in connection with the development of modern high range guns.

4. *Penetration Apparatus.*—Usually applied to standard rifles and guns, and so arranged as to cause the projectile to pass through a number of equal sheets of resisting material.

5. *Gas Pressure Recorders.*—Usually in the form of crusher or cutter gauges which can be tapped into the barrel of a gun or cannon to record the maximum pressure developed at the point

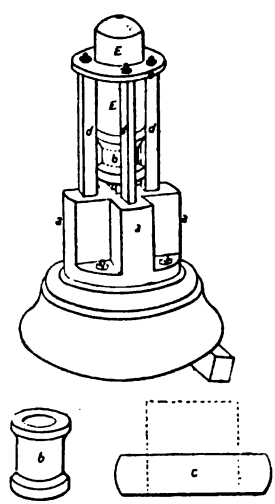


FIG. 2. Quinan Projection Gauge with Crusher Piece.

of insertion. The Rodman cutter gauge (U.S. 1857) and the Noble crusher gauge (Eng. 1860-68) are the best-known pieces of apparatus of this group. The latter is probably the more accurate. See Fig 5.

6. *Closed Explosion Chambers.*—These are provided with crusher or cutter gauges and gas checks to confine the gas produced by explosion and make it possible to determine the maximum pressure developed. The Guttmann gauge, Fig. No. 4, is of this class. In it lead cylinders are driven into the conical ends of the gauge and are thus deformed. The degree of deformation can afterward be measured with extreme accuracy, and from this the pressure can be calculated. The well known Noble pressure gauge (Fig.

No. 5) is also of this class and uses Noble crusher gauges to record the pressure.

7. *Independent Crusher Gauges.*—Usually hollow closed copper cylinders or small crusher gauges which can be put in a charge and which, if found after the explosion, show by their reduction in size the approximate maximum pressure to which they have been subjected.

8. *Devices for Miniature Blasts.*—Powder is exploded on the surface of or inside of some homogeneous material, such as wood or some ductile metal, and the size of the fracture or cavity

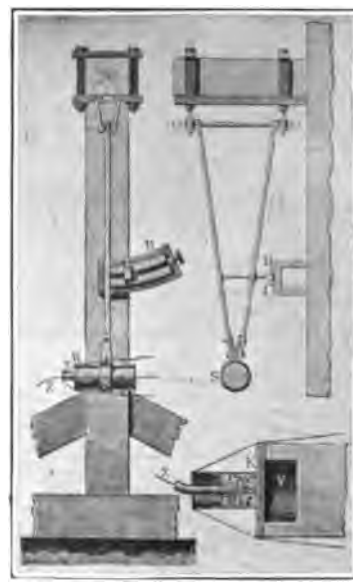


FIG. 3. Ballistic Pendulum.

produced is taken as a gauge of the power of the explosion. Gauges of this class will be discussed at length in a subsequent part of this paper.

9. *Chemical Analysis.*—In addition to tests with the apparatus above mentioned, in which powders are actually exploded, it should be explained that it is now possible to analyze any commercial explosive by standard chemical methods. Any well equipped modern chemical laboratory can make complete and sufficiently accurate analyses to determine the approximate com-

position of an explosive and its percentage of any such active agent as nitro-glycerine, gun-cotton, etc.

The five classes of apparatus first mentioned are all obviously intended for the investigation of guns and ammunition and need not be discussed at length here, although some of the gauges are most beautiful pieces of apparatus and of great value to ordnance experts. Among these may be named the Chronographic Velocity Recorders of Le Boulenger, Noble, and Mahieu, the Crusher Gauges of Rodman and Noble, and the Manometric Balance of Marcel Deprez.

Explosions in the closed chamber, Group 6, would at first seem likely to give results of use to engineers interested in blasting, but the conditions in a blast are really very different. In the blast, the enclosing substance always yields somewhat and if the

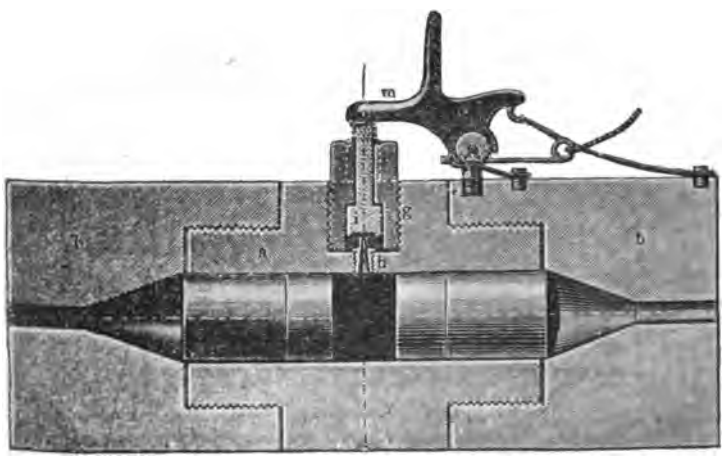


FIG. 4. Guttmann Closed Chamber with Lead Cylinder Crusher Gauges.

quantity and quality of powder are right, the material gives in many if not in all directions. The gases are thus permitted to expand, even while the explosion is still in progress, and although the leakage into fissures in the rock aids in the work of rupture, the temperature and pressure never rise to so high a degree as in a closed vessel.

Similarly, as the main object in blasting is to rupture a brittle substance and only secondarily to eject it, tests with projectiles in guns (class 1) are not properly comparable with blasts, and such a device as the Quinan gauge, although of great value to makers of powder who wish to exactly duplicate standard or

favourite grades, is certain to give misleading results if used to compare dissimilar powders.

Small crusher cylinders of Class 7 might be used to determine the comparative pressures of different blasts, but the shots would have to be of full size in order to get useful data, and the gauges would be difficult to find in the debris, and when found would often prove to have been damaged by falling rock. The author knows of no attempt to use these gauges except in connection with ordnance, in which case, gauges placed in the gun with the powder can usually be found near the muzzle, and if measured, give indication of the pressure to which they have been subjected.

The eighth class of miniature blasts offers a more hopeful field for experiment. Wood is a variable material, but metal need not be, and for some years the Trauzl cylinders of lead have been considered the best known devices for testing blasting powders.

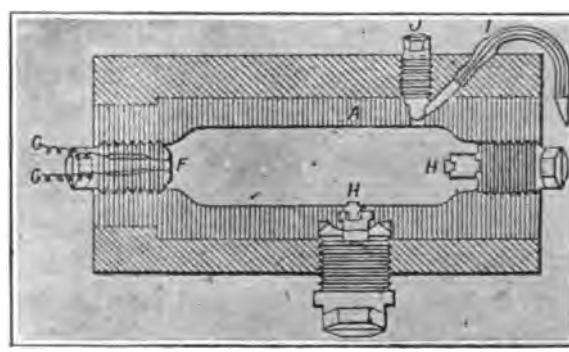


FIG. 5. Noble Closed Chamber Gauge with Noble Crusher Gauge to record Pressure.

As designed by Trauzl and described by such standard authorities as Guttmann, the apparatus is a cylinder of cast lead 200 mm. = 8″ in diameter, 200 mm. high, with a hole 20 mm.=$\frac{4}{5}$″ in diameter, and 110 mm.= 4⅜″ deep, cored axially from one end to just beyond the centre of the cylinder. Tests are made by placing a weighed quantity, usually 20 grms, of explosive in the cylinder, inserting a standard detonator with fuse, tamping lightly with dry sand, and firing. The hole in which the charge explodes is greatly enlarged, but the proportions of the charge to cylinder are such that the latter is not blown to pieces, and the exact dimensions of the cavity can easily be measured by filling it with water from a graduated vessel. The correction for the force of the detonator can be made by firing a second

but identical cap alone in a second cylinder and thus the actual power of the powder can be determined by something very similar to a genuine blast.

The most serious fault of the Trauzl test is that the proportions are not those of an ordinary blast, the hole is too short, the fuse is disproportionately large, and the tamping is very ineffective. As a result a very considerable part of the force of the explosion is wasted, and as this loss is greater for slow than for quick powders, the test is unfair to powders which required substantial tamping. Fig. 6 shows standard cylinders before and after a series of tests with different powders.

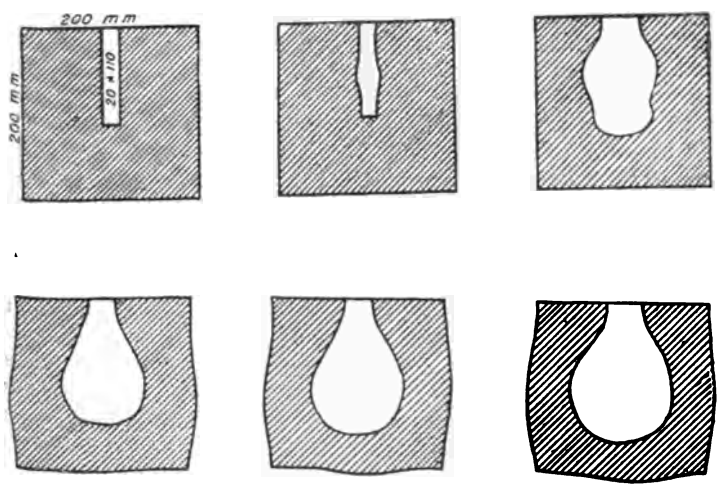


FIG. 6. Standard Trauzl Cylinders.

A few months ago the author had occasion to compare a number of powders, and being convinced that the proportions of the Trauzl cylinder could be changed with advantage, he calculated from theoretical considerations the shape of a lead cylinder in which shots could be fired without undue loss of force through the charging hole. As these cylinders are quite costly, and as each one can be used but once, it was undesirable to make them longer than necessary, yet it was equally important to make them long enough to hold a reasonable amount of tamping and thus to confine the gases until their work was accomplished.

After a number of experiments, cylinders of 125 mm.=5" in diameter, and 200 mm.=8" in height, were decided upon and the bore hole was made 12 mm.=15/32" in diameter and 135 mm.=5½" in depth.

As Trauzl cylinders of cast lead have often proved uneven in quality and even leak gas occasionally, arrangements were made to have these new cylinders manufactured in a lead pipe machine, from which the mandril had been removed and a solid cylinder of compressed lead just over 5" diameter, and many feet in length, was made on special order by the James Robertson Co., of Montreal. This cylinder was then cut into lengths and bored. Subsequent tests proved it to be of perfect homogeneity throughout. Charges of various sizes were used, but 8 grms. was found most satisfactory for high explosives. As the use of a fuse with the Trauzl cylinders seemed always to lessen the efficiency of the tamping, experiments were made with detonators fired by electricity and the small wires leading to these caps were found to interfere scarcely at all with the tamping of dry sharp sand which was run in on top of the charge and shaken down as compactly as possible. As the bore hole was much shorter even in these tests than in practical blasts, this sand tamping was further compressed by placing a lead weight of about 100 pounds on top of it. The cylinders when fired were, in all cases, placed upon an iron anvil weighing half a ton.

A large number of tests were made in these cylinders and the results were most satisfactory. Duplicates, which with ordinary Trauzl cylinders seldom agree to within many per cent., were found with the new cylinders to agree remarkably well. Differences of over one per cent. were very rare, and in most instances the checks were so exact as to be practically identical.

The half-tone cuts 7 to 14, show a series of these cylinders, and it can easily be seen that the conditions of the explosions in them must have been much nearer those of an ordinary blast than in the typical Trauzl cylinders figured above.

The tests above described are still far from being identical in character with standard blasting operations. Lead yields slowly to rupture, and even in the most extreme cases figured the cylinders did not absolutely fly to pieces, whereas blasts in rock, if effective at all, always rupture the material and afford the gas an almost free means of escape. The author believes, however, that tests made in cylinders proportioned as those he has described, will prove to be more fairly comparable with actual blasts than tests made in any other apparatus at present available. Probably the cylinders still give somewhat high results for quick powders, such as dynamite, as compared with slow powders, such

as common blasting gun powder, but this difficulty can no doubt be largely corrected by further changes in dimensions and by increasing the weight used to confine the tamping.

The most important thing remaining to be done, however, is to compare tests in the cylinders with the results of actual blasting operations on a large scale, and the real purpose of this paper is to interest practicing engineers in the matter, in the hope that they will keep careful records of the results obtained by the use of different makes and grades of powder, and will provide the author with samples of the powder used, so that he in turn may make tests in lead cylinders. By co-operation of this sort between field engineers and experimenters who are able to do accurate laboratory work, it is probable that some definite comparable relation can be proved between practical blasting in different classes of rock and under different conditions of work, and small scale experiments such as have been described.

The author trusts that more than one of his readers will be sufficiently interested to co-operate with him, and he will have great pleasure in making tests and publishing the results of tests on any powders for which sufficiently accurate and practical data are furnished. If these joint experiments bring out some consistent relation between laboratory tests and field work on different classes of rock, the engineering profession will benefit greatly, as it will at once become possible to determine in advance the approximate working strength of different powders and to tell which one will be most suitable for any particular work in prospect.

The following table shows the size of the cavities produced in the cylinders figured in Cuts 7 to 14. The cavities were measured by running in water from an accurate burette, and correction has been made for the volume of the original bore hole and for the effect of the cap. Powder No. 1 was so-called 75% dynamite. and No. 2, was so-called 40% dynamite. By analysis these powders gave 74.25% and 37.65% respectively of pure nitro-glycerine; both were from a well-known manufacturer. Powder No. 7 was a standard black blasting powder from a well-known manufacturer. Powders No. 65 and 75 were experimental explosives of fair quality and uniform composition. Powder No. 50 was an experimental explosive which proved extremely variable, owing to some fault in composition or manufacture. No two tests with this powder gave even approximately equal force, and one or two lots failed to explode.

TABLE OF RESULTS.

Fig. 7.	Bottom	Cylinder,	style	A—not fired.				
	Top	"	"	"	Cap only.		Enlargement	2 cc.
" 8.	Top	"	"	"	Powder	7*	"	15½ "
	Bottom	"	"	"	"	50	"	58
" 9.	Top	"	"	B	"	50	"	140
	Bottom	"	"	"	"	50	"	37½
" 10.	Top	"	"	"	"	65	"	170
	Bottom	"	"	"	"	65	"	173
" 11.	Top	"	"	"	"	75	"	237
	Bottom	"	"	"	"	75	"	243
" 12.	Top	"	"	"	"	2	"	274
	Bottom	"	"	"	"	2	"	273
" 13.	Top	"	"	"	"	1	"	473
	Bottom	"	"	"	"	1	"	471
" 14.	Experiments with charges of wrong size.							

The Style A cylinders were made lighter than standard for use with weak powders only. The B cylinders were of the dimensions stated in the paper.

Acknowledgment should be made to Guttmann's valuable works on High Explosives for Figures 1 to 4.

*A duplicate not figured gave enlargement of 14¼.

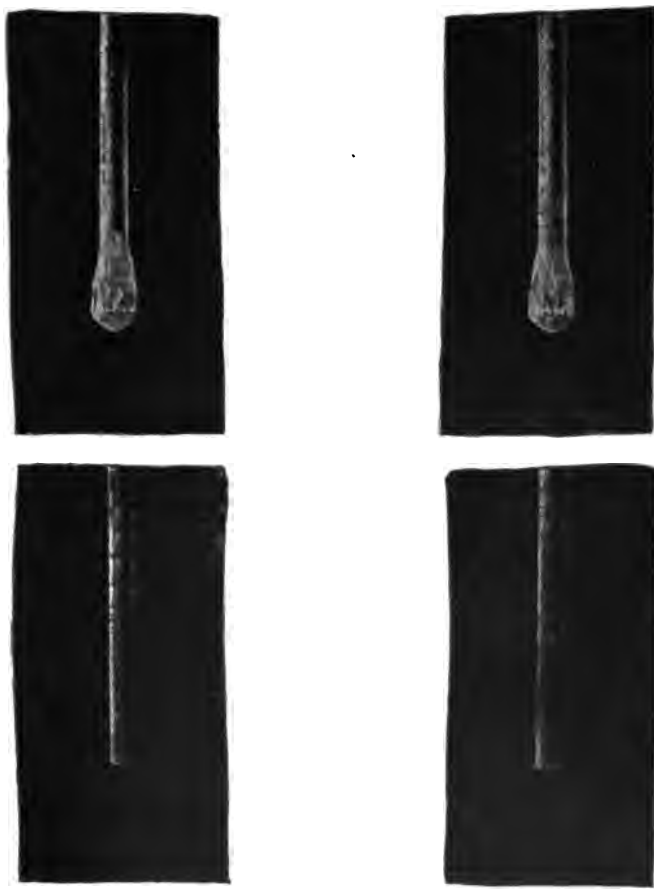


FIG. 7.

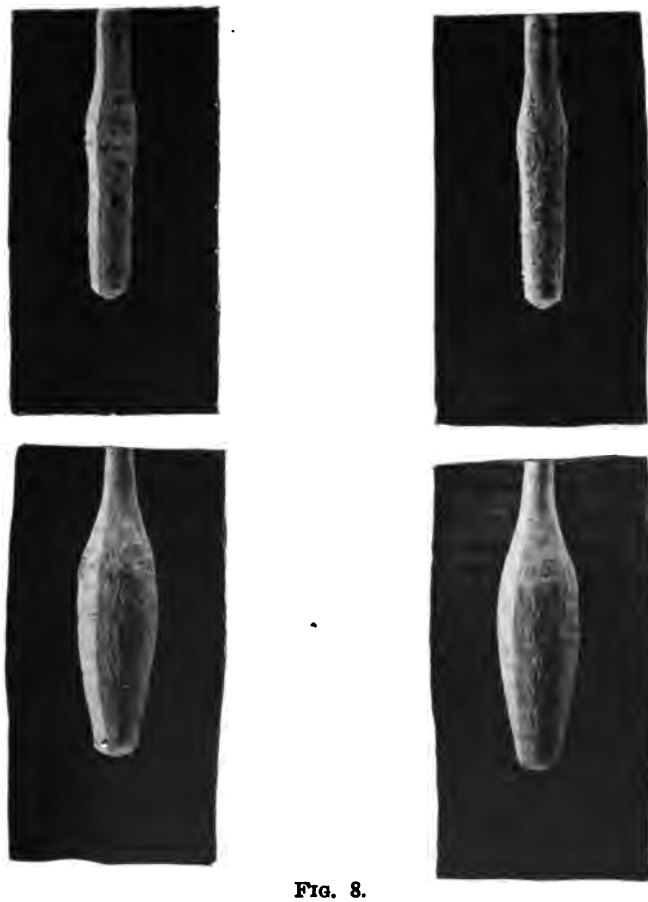


FIG. 8.

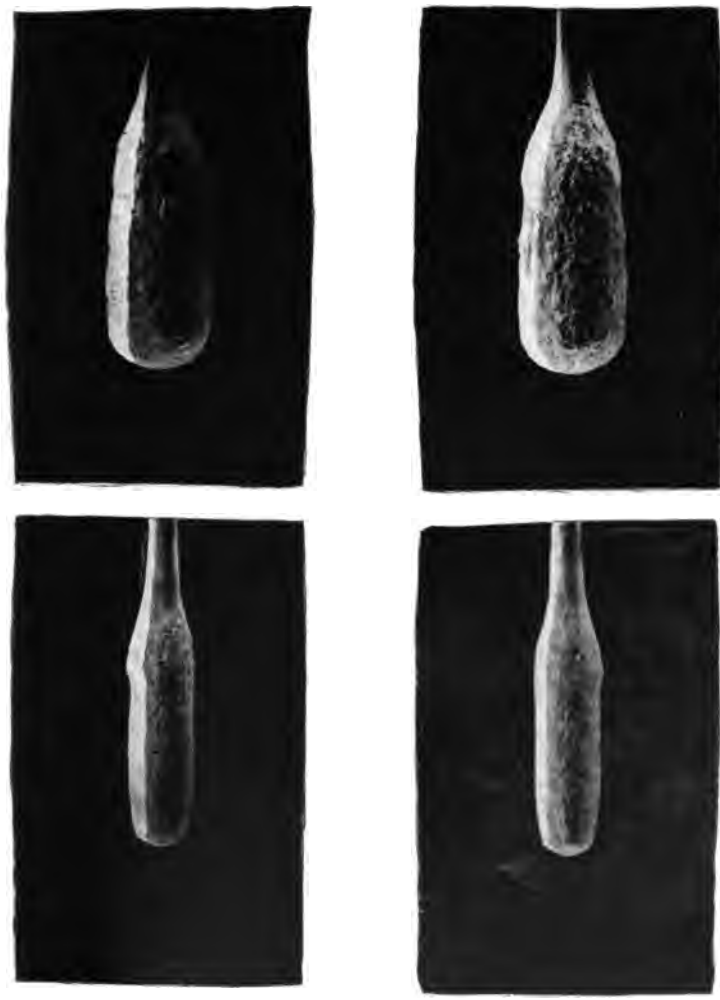


FIG. 9.

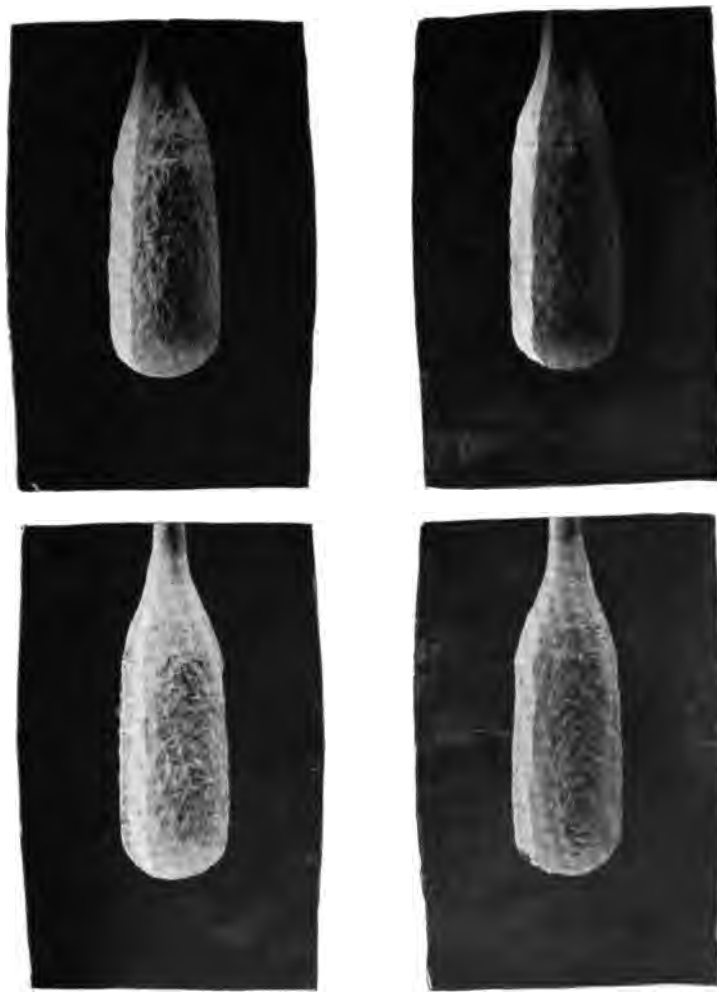


FIG. 10.

FIG. 11.

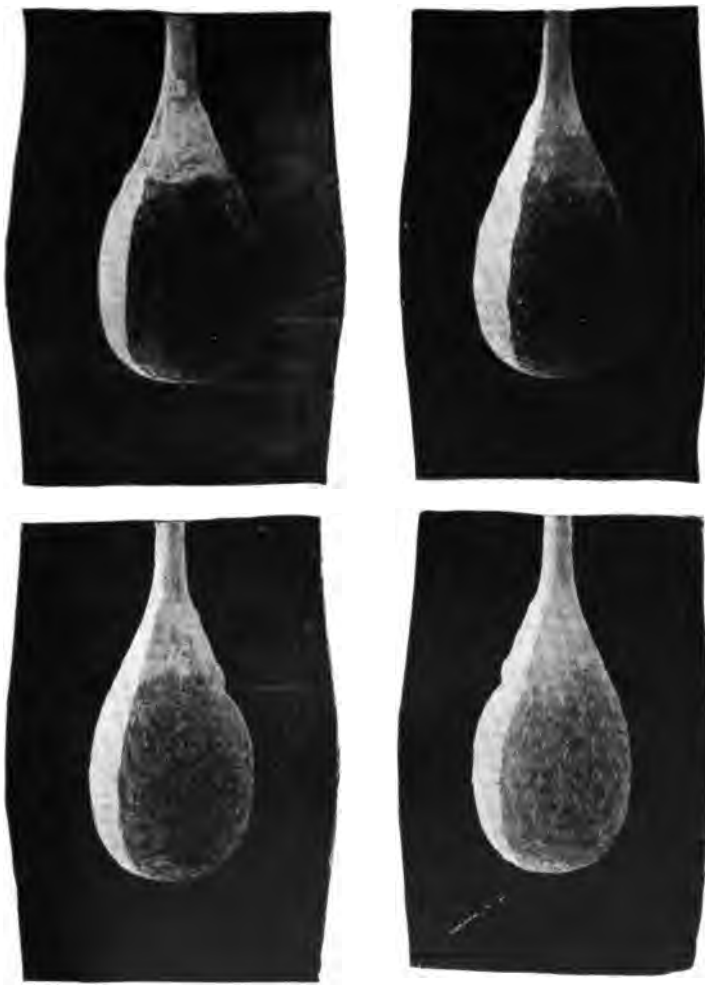


FIG. 12.

FIG. 12.

FIG. 14.

PAPER No. 234.

NOTES ON SOME RECENT EXPERIMENTS ON THE MAGNETIC CONCENTRATION OF IRON SANDS FROM THE LOWER ST. LAWRENCE.

By JOHN F. ROBERTSON, M.Sc., S. Can. Soc. C. E.

In attempting to use the iron sands from the lower St. Lawrence in a blast furnace, three difficulties are met with:—

First, the low percentage of iron on account of the dilution of iron bearing minerals with ordinary sand;

Second, the presence of an amount of titanium much greater than that usually considered permissible in an iron ore;

Third, the fineness of the material.

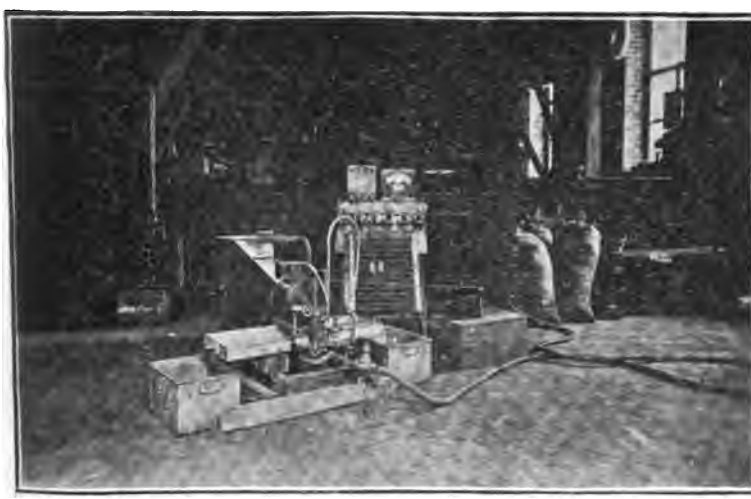


FIG. 1. View of Apparatus.

The third difficulty can be overcome by briquetting and may be left to the metallurgist. This note deals only with attempts to cheaply overcome the first and second difficulties.

The apparatus used in the experiments described below is of special design based on the Heberli drum separator. It consists of a thin hollow brass cylinder about eight inches in diameter and six inches long, revolving loose on a hollow axle through which wires are passed to a set of eight electro magnets arranged radially around the axle, and together filling one-half of the drum. The pole pieces just clear the inside of the brass cylinder.

Each has a width of ¾ to 1¼ inches as desired, perpendicular to the axis, and a length of about six inches parallel to it. Each magnet is wound with fifty-five turns of insulated wire, and the wires are led out through the hollow axle to a connection board so arranged that the magnets can be connected in series, or

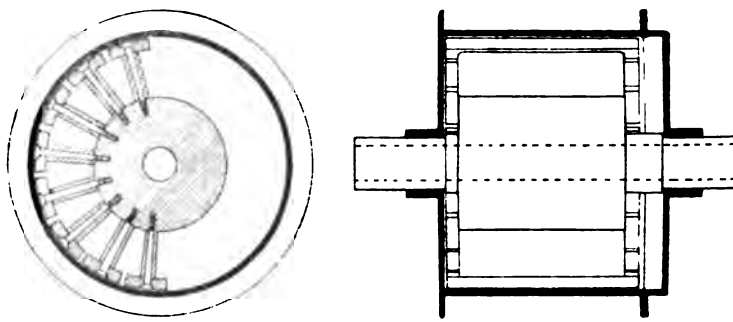


FIG. 2.

Sectional Elevations of Separator.

parallel, and each can be given either north or south polarity. In the experiments described below, the magnets were all in series, with alternate polarity thus: N-S-N-S-N-S. The magnets do not revolve with the cylinder, but may be set to cover any 180 degrees of its circumference desired. The sand is fed to the machine from an adjustable hopper which can be placed in different positions so that the feed can be run in at the top or at any part of the side of the revolving cylinder. Fig. 1 shows a photograph of the whole machine and Fig 2 two sectional elevations of the cylinder.

The advantage of having the magnets of alternate polarity is that the little grains of iron are turned end for end in passing each magnet. As there are eight magnets, the grains of iron are reversed six or seven times, and in trying to arrange themselves to suit the magnetism of the various poles they liberate the grains of sand which might otherwise be entangled in a bunch of grains of iron and thus be carried over into the finished product.

The apparatus was designed to be run either dry or wet and the drum can be rotated in either direction and at a great variety of speeds.

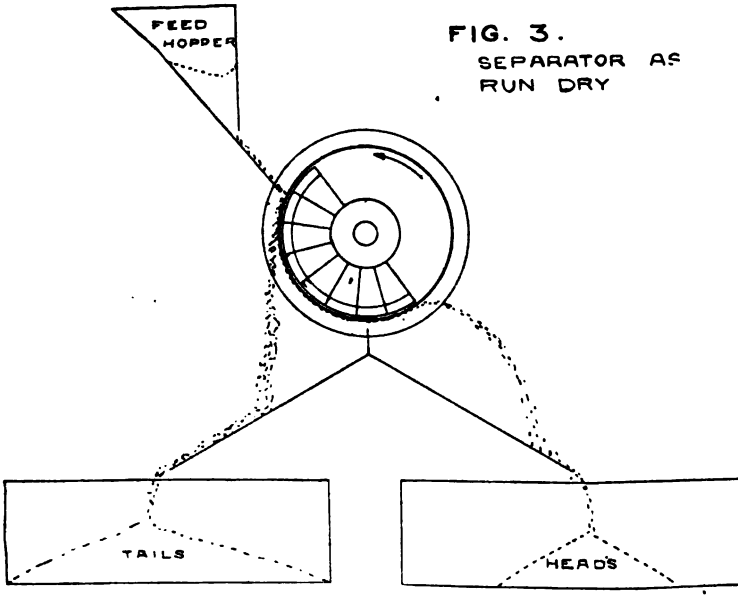


FIG. 3.
SEPARATOR AS RUN DRY

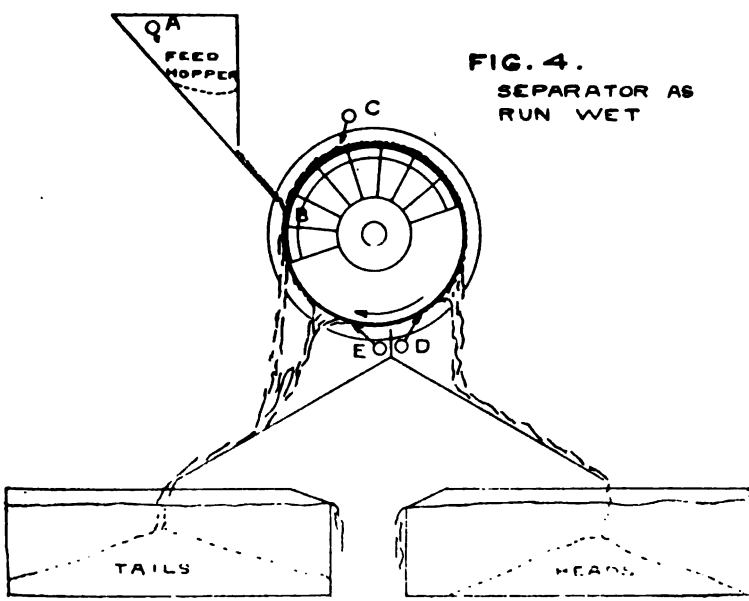


FIG. 4.
SEPARATOR AS RUN WET

In concentrating dry sands, the machine is run as in Fig. 3, the sand being fed near the top of the revolving cylinder. The non-magnetic material is collected directly under the edge of the cylinder, while the iron, pulled radially by the magnets and moved by the cylinder, passes under the latter and falls off on the other side.

When working with wet sand, the cylinder is rotated in the opposite direction, and the sand fed against the side about half way down. The sand, with some water from the jet A (Fig. 4), reaches the cylinder at B. That part of the cylinder is moving upwards, and the friction of the magnetic material as pulled by the magnets is great enough to carry it with the cylinder against the stream of water from the jet C. The non-magnetic minerals not being attracted, are washed down and away. D and E are two water jets to clean the cylinder from any materials which tend to adhere beyond the proper points for discharge.

It was found that the co-efficient of friction of magnetite on brass is so low that the grains tended to accumulate in rows in front of each pole piece. This difficulty was overcome by placing a few strips of electric tape across the drum parallel to the axis. Covering the drum with canvas was also tried, but while this gave good results in dry concentration, it carried too much non-magnetic stuff when run wet.

The magnetic field utilized in the separator is the stray field. As first designed, the gap between the pole pieces was made quite small, with the result that a large current was required to produce a sufficient strength of stray field outside the cylinder. The gap was then widened, giving better results. It is now proposed to further increase the air gap between the pole pieces, and enclose the whole working side of the apparatus in an external shield or armature. This will cause a stronger and more even field to pass through the drum, and will make it possible to secure the present strength of field with far less current.

The only dry run that has been completely assayed was on a sample of sand containing about 57% metallic iron and 16.2% TiO_2. It is probable that the major part of the titanium was in the form of ilmenite. Some may have occurred as rutile, and some no doubt was contained in minute grains of ilmenite enclosed in magnetite. Assuming that the titanium occurred as ilmenite ($Fe\ Ti\ O_3$) the 16.2% of TiO_2 had combined with it 16.2 x 56/80=11.3% of iron, so the amount of iron capable of being magnetically separated from the titanium would be only 57.0—11.3=45.7%. If rutile (TiO_2) was present the percentage of iron free from titanium may have been more. If much titanium was enclosed in magnetite the free iron may have been less.

As preliminary work, several field strengths were tried, the weakest used gave practically no concentrates, while the strongest took out nearly all the titaniferous material as well as the magnetite. As magnetite has a much higher magnetic permeability than ilmenite, there should be some strength of field at which the heads product obtained contains almost all the magnetite and still very little ilmenite. Unfortunately grains of ilmenite cannot be distinguished by the eye from grains of magnetite and assays for titanium in the heads and for iron in the tails should have been made to show what were the limiting amperages for successful concentration. In the test in question, this was impracticable and a current of seven amperes was used.

The result from 52 lbs. of sand was 22 lbs. of heads assaying 70.46% of metallic iron and 1.91% of TiO_2 and 30 lbs. of tails assaying 45.30% of metallic iron and 23.30% of TiO_2. This works out to a recovery in the heads of 65% of the total free iron, the heads carrying less than 1/16 of the titanium. A considerably better recovery than this could have been obtained with a slightly higher amperage and no harm done to the product as iron ore having 2.5% of TiO_2 or under is not objected to by blast furnace people.

A screen analysis of 43¼ lbs. of tails from a somewhat similar dry run showed:

(1) Remaining on an 80 mesh sieve.. .. . .. 9¾ lbs.
(2) Remaining on a 100 mesh sieve.. .. .. .. 27¾ lbs.
(3) Passing through a 100 mesh sieve.. .. .. 5¾ lbs.

Assays of these sizes showed:

	Fe%	SiO_2%	TiO_2 and Al_2O_3%
Over 80 mesh.....	35	15.0	35
80 to 100 mesh.....	42	4.5	35
Under 100 mesh.....	60	1.5	15

The capacity of the machine dry is about 300 lbs. per hour. Its resistance as used is 3 ohms, so the magnets with seven amperes passing required about 150 watts or 1/5 H.P. It takes less than 1/5 H.P. to drive the cylinder, so the total consumption of power is less than one-half H.P. A large machine designed for economy of power could easily do equally good work with one-half or one-third of the current and power per unit weight of sand, viz., from 100 to 150 watt hours per 300 lbs. At 10 cents per killowatt hour, this would amount to 7 to 10 cents per ton of sand. The capacity can probably be further increased by running any but very rich sands very fast so as to make a large amount of poor heads, and then cleaning these heads by re-running them.

Run wet, the machine will probably duplicate the work it does dry, but the adjustments need more careful watching and the capacity is lower. Six wet runs on sands from Seven Islands gave heads containing 1.10, 2.36, 2.30, 1.48, 1.48, and 1.67% of TiO_2. Preliminary runs on each ore and numerous assays are necessary for the determination of the adjustments required. A wet run for the exhibit of the Quebec Government at the Liege Exhibition, which had to be done without assays or sufficient preliminary work, gave concentrates carrying 7.13% of TiO_2. This sand was practically identical with that used in the six wet runs mentioned above, all of which gave very low titanium in the heads. The assays made after the test was completed, are as follows:—

Heads	Metallic Iron	64.31%
	TiO_2	7.13%
Tails	Metallic Iron	44.95%
	TiO_2	20.17%

The weights were:

Heads	27 lbs. 12 oz.
Middles (not exhibited)	3 lbs. 10 oz.
Tails	27 lbs. 11 oz.

61% of the free iron was got into the heads with about 1/5 of the titanium. The sand was the same as that used in the dry run previously described, and is practically identical with that which gave such excellent results when preliminary assays were made.

The capacity of the separator wet is about 100 lbs. per hour. About 0.02 cu. ft. of water per minute is required to reduce the damp sand to a pulp, and about 0.10 cu. feet per minute to wash the tails from the heads. Sometimes water is used for cleaning the heads and tails from the bottom of the cylinder and sometimes not. The water could easily be pumped back and used over and over. The total power used in the present small machine when running wet costs on an average about 50 cents per ton of sand, but on a large machine this could certainly be cut down to one half or one quarter that amount. The separator either wet or dry is usually run at 87 revolutions per minute. The amperages used range from 3 to 11, 5 and 7 being the commonest.

The machine used in the above tests was designed by Dr. J. B. Porter, Professor of Mining Engineering, and built in the shop of the Mining Department of McGill University. The work detailed was all done under his advice and general direction. but great credit is due Mr. R. A. Chambers, a former student, for tests which he carried out on the Seven Islands sand. The

author is responsible for the more recent work, and thanks are due Mr. J. Obalski, the Mining Engineer of the Province of Quebec, for material. The chemical analyses were nearly all made by Mr. M. L. Hersey, Provincial Analyst, by authority of Mr. Obalski. The main part of the sand was furnished by Mr. William Robertson, of Montreal, but the Seven Islands sand came from Mr. Ganong, of Quebec. The wet and dry tests last made were carried out at the suggestion of Mr. Obalski and samples of all products were included in the Canadian Exhibit at Liege this year.

On the conclusion of the paper the author exhibited a set of samples of the sand sent to Liege, as follows:—

1: Original sand.
2: Heads of dry concentration.
3: Tails dry concentration.
4: Heads of wet concentration.
5: Middles of wet concentration.
6: Tails of wet concentration.

DISCUSSION.

Dr. Porter

Dr. Porter remarked that the problem of the magnetic concentration of St. Lawrence iron sand had been a source of interest for a great many years, and the results of Mr. Robertson's experiments would be of interest to all who read his paper.

Regarding these last tests for the Quebec Government, which, as Mr. Robertson had said, were made without sufficient analysis, the need of making careful analysis if accurate results were required was fully appreciated, but the Quebec Government did not make their final arrangements until the time was so short that chemical work could not be done. Mr. Robertson had to guess what would be about the right percentage of current and then sent the sand off to Belgium. Very much better work could have been done had there been more time, and the fault was not from lack of knowledge, but from circumstances. Mr. Robertson had given details of current, etc., which would be of value to anyone studying this subject. All must bear in mind that work with this experimental machine would be more expensive than with an actual commercial machine. The machine was designed for various kinds of work. If they were to design another especially for titaniferous sands, it could be made to work far more economically. The Federal Government had arranged to have a large amount of the magnetic sands collected and arrangements would probably be made to have them tested and smelted. Both Government and private individuals were interested in the matter.

The point brought out in the tests, with a machine which was not economical, was that they had succeeded in getting a comparatively cheap method of separating the iron from the titanium. This was purely an experimental machine and had different adjustments for different experiments, but no adjustment for economy of current.

One means of cheapening the results and getting more effective magnetism would be to enclose the whole machine in an external armature. By referring to Figure 2, all could see that the pole pieces were inside the drum and anyone acquainted with the laws of magnetism would see that only a very small fraction of the field induced by these magnets was utilized. By changing the drum, and especially by using an external armature, it would be possible to get a much greater number of the lines of force to come out through the drum, and, therefore, to be of use.

Mr. G. H. Dawson referred to Figure 4, and asked the reason why the magnets were continued so far around the drum. The magnets took the material around to almost the last quarter and it seemed that an unnecessary amount of power was used. Mr. Dawson

Mr. Robertson explained that an unnecessary amount of power was certainly used. However, the machine was built as an experiment and with a commercial machine probably two-thirds of the power could be saved. Mr. Robertson

In his early experiments he had failed to sufficiently separate the titanium from the iron and the important point now was that at last they had a machine which would differentiate between the two, and that fairly good economical results had been obtained. The object of the University was to prove that it was possible to separate these two and it was left to commercial people to work out the other details.

Mr. W. A. Duff said that he understood they were unable to get all of the titanium out by this process and that there was enough left in to be objectionable. Mr. Duff

Dr. Porter replied that this question had been taken up with blast furnace people, who informed him that it was the general practice to look upon 2% of titanium as harmless and that it was only seriously objectionable when it rose to 4% or 5%. He did not think it was possible to get all the titanium out, as the minerals did not occur in the free state but in the form of an intimate mixture of mgnetite and ilmenite, and as it had been proved possible to separate down to a point where blast furnace people could not find fault, he considered that the experiment had proved very satisfactory. He had no doubt that they could separate far better, but it would entail greater cost and more loss of iron. Dr. Porter

Mr. Duff said he understood there were ores somewhat similar to the one described containing manganese, and asked if it were possible to concentrate them also. Mr. Duff

Dr. Porter replied that he considered it possible, but he knew of no attempt to make the separation in any Canadian ores, and therefore he could not say definitely what the result would be. Dr. Porter

PAPER No. 235.

NOTE ON A NEW INSTRUMENT FOR SURVEYING DEEP BORE HOLES.

By J. B. Porter, D.Sc., M. Can. Soc. C. E.

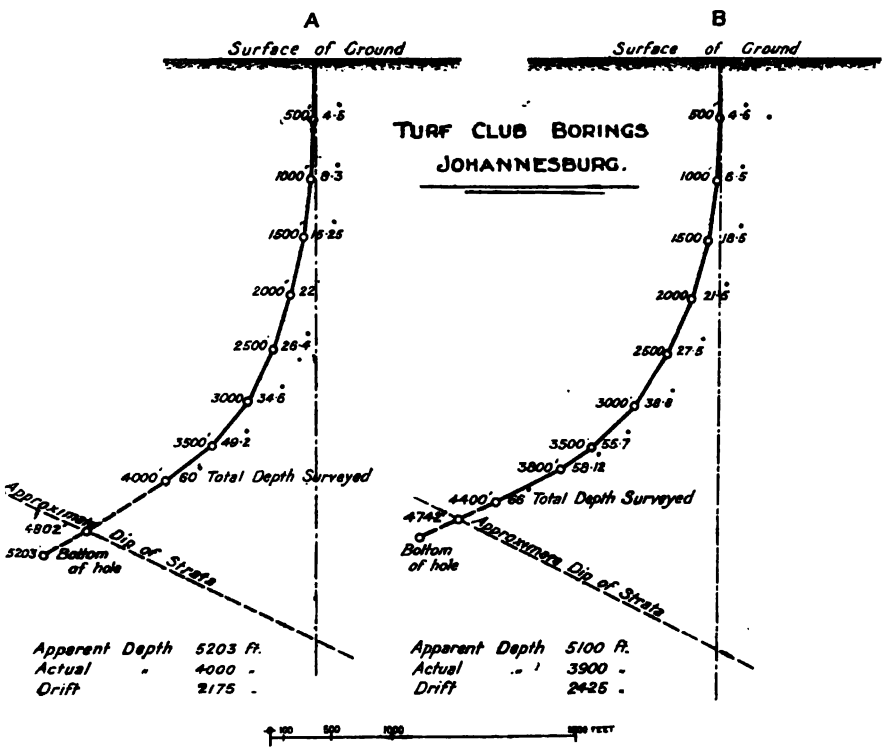
It is a well-known fact that deep borings are seldom true, and although artesian wells seldom depart very much from the vertical owing to the method of drilling them, yet diamond drill holes and other borings with rotary apparatus very frequently drift very far out of line. So long as the hole is not deep this drifting is not a serious matter, but on holes of say 1,000 feet, the departure from line sometimes exceeds ten per cent. In extreme cases such as certain very deep recent borings near Johannesburg, holes which were intended to be vertical have drifted more than 2,500 feet to one side of their aim.

In view of the great cost of these deep borings it is extremely desirable that the exact location of cores brought to the surface should be determinable, and a number of devices have been introduced within the last few years for the purpose of surveying holes. Most of these devices are comparatively crude and their use involves a great deal of labor.

The apparatus most generally used of late years has been a cylinder of glass, partially filled with hydrofluoric acid. This cylinder, usually less than one inch diameter, is enclosed in a brass case and attached to the end of a string of screwed rods and lowered into the hole to a known depth where it is left for some hours and then withdrawn. The inclination of the hole can easily be read from the glass vessel, as the upper surface of the hydrofluoric acid etches the glass quite distinctly, but the direction of the hole can only be determined by marking the orientation of the top rod while the etching is taking place, marking each joint when the rods are taken apart and finally screwing them together again on the surface in order to compare the orientation marks with the etching on the glass tube. By surveying points at distances of say 300 or even 500 feet, the general course of a bore hole can be determined by the method above described, but the method is laborious and costly and owing to almost unavoidable twisting of the rods the results have seldom proved very satisfactory.

Another method of surveying involves the use of plummets and compasses immersed in a solution of gelatine which slowly hardens after the apparatus has been sent down the hole. This device, although very ingenious, has proved very difficult in use

and has not met with much success, especially in deep holes. A very recent form of the apparatus uses paraffine in place of gelatine. The instrument contains an electric resistance and is connected with a dynamo on the surface by double insulated cables. The compass and plummet remain fixed in the solid paraffine while the instrument is lowered to the station in the hole. Current is then sent through the cable and the paraffine melted. The current is then shut off and after sufficient time has elapsed for the paraffine to solidify the instrument is reeled in and its records



read. The apparatus should give accurate results, but the long line of insulated cable is costly and liable to injury. (Marriott—Trans. Inst. Min. and Met., Feb., 1905.)

A few months ago an instrument maker in Johannesburg designed a very ingenious apparatus containing compass, plummet, small cameras, and electric lights, the whole connected with a small adjustable clock so that the light could be turned on for a given period after the apparatus had been lowered into the hole. This apparatus was described by its inventor, Wm. Helme,

at a meeting of the Institute of Mining Surveyors of the Transvaal on May 27th, 1905. It has since been used in surveying a number of holes and has proven extremely satisfactory.

A prominent mining engineer of the author's acquaintance states that he has had the machine tested by surveying several holes twice and has found the readings to agree so closely in all cases that he scarcely considers it necessary to take check readings unless the first set show some unusual change of direction in the hole. The apparatus, instead of requiring rods, the use of which involves a great expenditure of time and labor, and the use of a derrick and a power hoist, can be lowered on the end of a piece of flexible wire from a large reel and thus several observations per day may be taken by two men.

The writer has not had an opportunity to use the instrument in actual surveying, but has taken a number of observations with it on the surface and has found its records interesting and apparently exact. He therefore feels justified in submitting the following brief description of the instrument taken from the original paper by its inventor:

GENERAL DESCRIPTION.

Briefly described, this instrument is one in which both dip and deviation are recorded by means of photographs of the positions of both a plumb-bob and a magnetic needle at any desired point in a borehole. The photographs are taken by means of two small electric lamps lit by a "time contact."

DETAILED DESCRIPTION.

The instrument comprises a brass cylinder 20 to 30 inches long; both length and diameter are varied to suit the particular requirements. The cylinder is made in two portions, which screw together quite flush shoulder to shoulder. The top and bottom are closed by means of tightly-fitting screwed plugs. To the top plug is attached a brass swivel with an eye piece, by which the instrument is suspended. The swivel is fitted to the plug with ball bearings. The object of this swivel is to prevent the wire, which is used in lowering the instrument, from twisting; also, to minimise risk of the instrument kicking against the sides of the borehole when being lowered or raised. Inside the cylinder, immediately beneath the top plug, is a spring resting on a pad, which keeps firmly in position a small watch or timepiece. Below the watch is a dry battery. Below this again is arranged a tiny electric lamp, and below the lamp is a glass plate, from the centre of which hangs a small plumb-bob. Below the plumb-bob is a circular brass plate supported on gimbal bearings, so that it always remains in a horizontal position. On this plate is placed a small disc of sensitised paper. Below this is another electric lamp, and below this again is a compass, which is also supported on gimbal bearings. On the dial plate of the compass is placed another disc of sensitised paper; each disc is pierced by a pin-prick in the centre, and another on one side, and both discs are fixed in exactly the same relative position, one above the other, when in the instrument. The whole is kept firmly in position from below by another spring placed under the little cup holding the magnetic needle, and resting on the bottom screwed plug. When the hand

of the watch is passing the 12 o'clock point on the dial, it makes contact for about 15 seconds with a small projecting spring made of copper foil, which is connected with one line from the battery. The hand of the watch is connected with the other line; and so, when in contact with the spring, the circuit is completed; both electric lamps are lighted; and photographs are taken of the positions of the plumb-bob and the magnetic needle. It is only necessary to set the watch so that the hand will only pass the 12 o'clock point after sufficient time has elapsed to allow for the instrument being lowered to the required depth, and also to allow for the plumb-bob and magnetic needle having come to rest. In practice, it is usual to take readings at, say, every 200 feet to 300 feet, and two readings should invariably be taken in each instance. When once the photographs have been obtained, the rest of the work is easy; for, the height of the point of suspension of the plumb-bob above the centre of the disc being known, and the distance of the lower end of the plumb-bob from the centre of the disc having been obtained by accurately measuring the distance between the centre of the photograph of the plumb-bob and the centre of the disc, the angle of dip can be calculated. The direction is also easily obtained by placing the two discs in the same relative positions which they occupied while in the instrument, which can at once be done by means of the two pin-pricks on each. The direction of the line joining the centre with the image of the plumb-bob on the one disc will then (unless it happens to fall in the magnetic meridian) make an angle with the photograph of the magnetic needle on the other disc, and from this angle the magnetic direction of the path of the borehole at that particular point is determined. In surveying a borehole, say 4,000 feet in length, two sets of readings should first be obtained at regular intervals, which should not exceed 250 feet in length. When these have been obtained, the dip and deviation must be calculated for each point, and then sufficient data are available to plot, in plan and section, the true path taken by the borehole. (Proc. Institute of Mine Surveyors, Transvaal, May 27, 1905.)

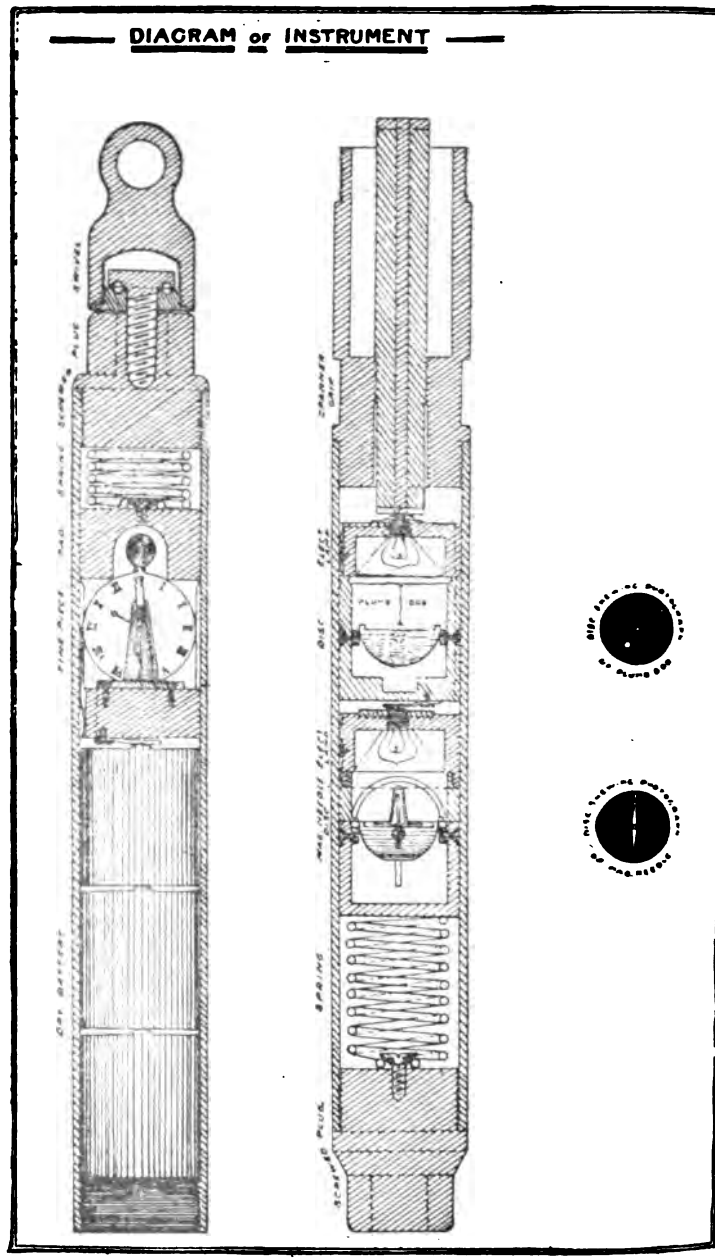


DIAGRAM OF INSTRUMENT
SPRING
SCREWED PLUG

DISCUSSION.

Prof. McLeod having been asked by the Chairman to give his opinion on the different instruments spoken of, and especially the Helme instrument, said that short of sending a surveyor down a hole he thought the machine was about as complete as could be devised and that it was well calculated to overcome the objections which existed in regard to these surveys. While he had no acquaintance with this class of survey, except from books, he thought in the older method, which depended on the action of hydrofluoric acid on glass, some of the apparatus had been provided with compasses released and then locked by means of a clock-work, which overcame the difficulties mentioned in the paper. Prof. McLeod

Dr. Porter said he knew of this method, but he believed it had never proved very accurate. It was not now used to any extent. He had omitted it and several other methods, for lack of time, and had only mentioned in this paper the more commonly-used devices. Dr. Porter

GENERAL SECTION.

President—PHELPS JOHNSON.
Vice-President—C. H. RUST.

A meeting of the General Section was held on Thursday, December 14th, 1905, Mr. Phelps Johnson in the chair. The following three papers were read:

PAPER No. 236.

THE GRAND RIVER, ONTARIO PENINSULA:

Effect of Deforestation and Swamp Drainage.

By W. H. BREITHAUPT, M.Can.Soc.C.E.

The peninsula of South-Western Ontario is remarkable for the great bodies of fresh water surrounding it. Taking as north-easterly limit the shortest line between Georgian Bay and Lake Ontario the area of the peninsula is 16,500 sq. miles. The area of the abutting bodies of water, Lake Huron, Lake Erie, and part of Lake Ontario, is 33,900 sq. miles, while adjoining Lake Huron on the west and north-west are Lake Michigan, 25,000 sq. miles, and Lake Superior, 32,000 sq. miles.

In topography the Peninsula presents what may be called a table land, comprising parts of the counties of Grey, Wellington, and Dufferin (see map, Plate 1,) from which the surface slopes in every direction, abruptly to the north, where the fall is over 1,100 feet in a little more than twenty miles, more gradually towards the west and still more so towards the south-west and south, to the almost level rim of surrounding water, the difference in level between Georgian Bay and the inlet of the Niagara River, i.e., between Lake Huron and Lake Erie, being only about nine feet. In general the surface is rolling. A broad, flat area extends for the greater part from the outlet of Lake Huron along the southerly limit of the peninsula almost to Lake Ontario. A peculiar feature is the Niagara escarpment, an abrupt rise of 200 to 300 feet defining the difference in level between Lake Erie and

Lake Ontario, and extending along the south shore of Lake Ontario at a distance of from five to ten miles to Hamilton, where it is near the head of Burlington Bay. Thence it stretches to the north and is well defined for a long distance. To the east of what has been called the table land a broad ridge forms the watershed between Georgian Bay and Lake Ontario, sloping down to the level of Lake Simcoe, which is 140 feet above Georgian Bay and 475 feet above Lake Ontario.

Westerly winds are largely preponderant. Graphic evidence of this is afforded on the exposed islands of Georgian Bay, where the wind has almost a clear sweep for 500 miles, by the scrub pine with their well marked slant and their branches mostly on one side of the trunk. The origin of most of the precipitation is herewith indicated. A large part, especially in the south-easterly part of the Peninsula is, however, also due to east winds over Lake Ontario.

Originally the Peninsula was covered with an almost continuous heavy forest of pine and hardwood, interspersed with swamps. In 1901 the woodland area had been reduced to 14.9% of the whole, and since then it has become still less. A large decrease of woodland was noted from 1897 to 1901. There are a few comparatively small forest reserves in Ontario, but none in the Peninsula.

What climatic change has been caused by deforestation is not definitely known. Variations in temperature seem to have become much greater and more abrupt, and transition between the seasons of the year also more abrupt. The forest cover kept the ground moist after rainfall and retarded melting of the snow. Precipitation records have been kept at various points on the lakes for over sixty years. In Toronto the records date from 1840, for which year the record is 29.57 in. rainfall as against 30.4 in. in 1904. The average total precipitation, dividing snowfall by 10 to reduce to water, for sixty years is 33.0 in., with minimum 24.37 in. in 1874, and maximum 48.49 in. in 1878. For the past ten years the average is 31.1 in. There is to be said that rainfall and snowfall observations are at best only approximate. There is a personal equation of the observer, and results have been found to vary materially with the height of the instrument above the ground, other conditions being alike. In the interior of the Peninsula records have been only recent, for about the last twenty-five years, but fairly well distributed. From a table compiled for the years 1883 to 1888 it appears that the greatest precipitation is near the height of the north-west slope, over 40 in., other areas showing mostly 35 to 40 in., and 30 to 35 in. In passing it may be said that this is very favorably above the minimum of 20 in. accepted as necessary for agricultural or pastoral purposes.

It is clear that precipitation in the Peninsula is not materially affected by deforestation, but is due more to the permanent conditions already outlined. The run-off is, however, very directly affected. The forest cover not only checks evaporation and snow melting but renders the surface permeable so that the water finds its way more readily into the ground to appear elsewhere in the form of springs, and by drawing up and exhaling moisture beneficially affects the atmosphere. Large swamps are natural reservoirs, like great sponges, and are extremely valuable in giving regularity to flow of streams.

The drainage area of the Grand River, as shown in shaded outline (Plate 18), comprises nearly the whole of the counties of Wellington, Waterloo, and Brant, and parts of Dufferin, Halton, Oxford, Wentworth, Norfolk, and Haldimand, a total of 2,600 sq. miles, approximately one-sixth the area, and essentially the central part, of the Peninsula. In its original condition, about up to the year 1800, this whole area was densely wooded or covered with swamp. Some little clearing had been done before that date. From 1800 settlement extended as far as Waterloo County, which by 1820 was mostly taken up. From about 1850 on, settlement extended farther up, but the headwaters of the river in the townships of East and West Luther, Amaranth, Melancthon, and Proton remained practically intact until 1870. The township of Luther, now East and West Luther, as recently as 1871 is described as nearly wholly consisting of impenetrable swamp. The adjoining townships were largely swamp and partly hardwood forest. In the following years drainage of these townships, aided by special provincial legislation and provision of funds, became rapid, as did also the general clearing off of forests.

Up to about the year 1860 the flow of the river was fairly regular, with a good body of water throughout the summer and no great floods as a rule in the spring, except locally where the water might be held back by the formation of ice gorges. The spring freshets were in April or beginning of May, and only exceptionally as early as March. A record kept in Galt beginning with 1858 gives the spring freshets at that point as in March for the four years 1858, 1856, 1860, and 1861 (these years from other records appear to have been very low in snowfall) after which until 1877 they were almost all in April. After 1877 the floods were mostly in March and twice at the end of February.

The minimum summer flow seems to have decreased more particularly since about 1875, coincident with the drainage and clearing of the head townships. From fairly definite evidence at points in Waterloo Township the decrease in the past fifteen years appears to be fully 40% of the minimum in 1890. At Galt (total

drainage 1,325 sq. miles), and farther down the river the decrease appears not to have been so much. The Speed River empties into the Grand above Galt and the Nith at Paris. (Total drainage 2,020 sq. miles.) The drainage areas of these tributaries have not changed so much in recent years.

The proportion of woodland in the drainage area in 1901 was, by townships, as follows:—

Melancthon	16.2	Wilmott	10.2
Arthur	6.8	Waterloo	9.8
West Luther	7.2	Puslinch	6.9
East Luther	5.3	Blandford	12.4
Amaranth	1.9	Blenheim	8.5
East Garafraxa	6.8	North Dumfries	12.
Maryborough	14.3	South Dumfries	5.4
Peel	14.8	Beverly	11.8
Pilkington	6.5	West Garafraxa	1.4
Nichol	15.1	Burford	11.9
Eramosa	10.7	Oakland	17.3
Erin	5.8	Brantford	2.7
Mornington	10.8	Onondaga	9.
Wellesley	15.4	Townsend	12.8
Woolwich	13.7	Tuscarora	not given
Guelph	7.6	Oneida	11.1
Nassagaweya	21.1	Cayuga	24.4
North East Hope	10.4		

For the whole of the drainage area the percentage of woodland is 9.85.

The main source area of the Grand River may be considered as extending to Elora, above Pilkington Township, with a surface of about 425 sq. miles. The snowfall throughout this section is very great. At Fergus one snowfall year is recorded as 135 in., and a number of years are over 100 in. Formerly the forests and swamps retained the snow and let it off gradually. The country from the north of Melancthon to almost the south line of Luther Townships, an extensive plain, is now of hard surface, largely, though not mostly, in grazing land which can be traversed across country independently of roads in almost any direction. A few warm days in February or March start the run-off with a rush, and it takes but a short time for the accumulation of snow to disappear.

For comparison it will be of interest to note the forestation in some of the oldest and most thickly populated countries of Europe. A recent tabulation, 1902, gives the following percentage of forest to total area:—

Germany	26%
France	18%
Belgium	17%
Hungary	28%
Austria	32%
Spain	17%
Italy	14%

Could the forestation of the Grand River basin be increased to 20% or more there would be no question of great benefit in regulation of flow. The Provincial Forestry Reports class a large part of land as waste. The total in the Grand River drainage area from the 1901 report is 12.3%, the percentage being larger in the upper townships. Waste lands are given as including swamp and marsh. These are by no means waste when their river regulation value is considered, and for this purpose a large increase of swamp and marsh area would be welcome. There are also large areas of cleared non-arable land, and these present special opportunities for reforestation. In the United States reforestation in various parts of the country has become well established. In Massachusetts, the Boston Metropolitan Water Board alone reforests about 200 acres per annum.

When it is considered that the valley of the Grand River is already well populated, will in a short time have three large cities, Berlin, Galt, and Brantford on the river, and is and will continue to be, one of the foremost manufacturing districts in the Dominion, forethought and provision in the way of establishing conditions to benefit the climate and regulate excesses of the river must be held to be well worth while.

The available water power of the river and its improvement by regulation of flow is a feature of great importance. The total fall from Dundalk, with elevation 1,710 ft., to the mouth of the river is nearly 1,140 ft, Elevations are successively as follows:—

Grand Valley	1,510 ft.
Elora	1,250 ft.
Breslau	961 ft.
Galt	847 ft.
Paris	731 ft.
Brantford	641 ft.
Lake Erie	572.3 ft.

In many places there is a very considerable fall in a short distance. In Elora there is a single drop of over 40 feet, where the river enters a limestone gorge. The water power is made use of at a number of places along the river. Its value is greatly impaired by the extreme low water continuing for about two months in the year.

FIG. 1

FIG. 2.

The flow regulation of the river by means of large storage basins is for the present hardly practicable from an economical view point, and will not here be further considered.

The cross-section (Plate 19) taken three miles above Breslau, Waterloo Township, is a typical one for a large part of the river. The low water discharge at this point, as measured in September this year, is 82 cubic ft. per second. The spring flood discharge is approximately 10,500 cubic ft. per second, and has been considerably more. The maximum continues for a short time only, a few days at most. A heavy rain raises the water level very quickly, and has in recent years given a rise of as much as 4 ft. over night. At Brantford the spring flood in 1900 was 16 ft. above low water level. At Galt the minimum flow appears to be about 60% more than at the section given, this being due to the Speed River. Former spring high water and summer low water are shown approximately on the section. The photograph, Figure 1, taken near the section (Plate 19) shows recent high and low water levels, high water being about a foot above the bare place on the tree at the edge of the bank where ice has cut away the bark. Figure 2, near the same place, shows a small elm 8½ in. in diameter immediately above the ice-scarred part of the trunk. High water rises about 6 ft. on this tree. Its age would be about 30 years, indicating the probable period of ice floe encroachment on the ground at its base.

In conclusion it is to be stated that definite observations in the drainage basin are few. Precipitation records have been kept since 1881 only at Guelph at the Ontario Agricultural College, and these are much the most reliable; and at Brantford, Galt, Conestogo, Elora, and Fergus, for periods of from five to ten years. There are no data on run-off, except roughly general ones.

DISCUSSION.

Mr. Breithaupt

Mr. Breithaupt stated that a great deal of interest was being taken in a possible remedy for this condition of lack of forests, and the Dominion Forestry Association had been interested in the matter. It would carry a great deal of weight if the Canadian Society of Civil Engineers would represent to the Legislature of the Province of Ontario the necessity of some remedy for these conditions.

The farmers were not encouraged to leave their wood standing, as they had to pay high taxes for wooded lands, which returned nothing on their investment, except, perhaps, a little cordwood. If something were done in the way of lowering these taxes, it would probably be of some benefit. Many other suggestions had been made, and among these, at a meeting in Guelph, it was proposed that waste lands be planted with trees and the cost covered by taxation. At Berlin, the Water Works Engineers did not need to consider any such question, as they obtained their water supply from artesian wells, and at Galt a similar condition of affairs existed. A publication of the United States Geological Survey, in connection with rain-fall and run-off, stated that it was generally found that forests did not change the river flow very much, but equalized it. As a general rule, the relation of run-off to rain-fall was from 40 to 60 per cent., but often less than 40 per cent. of the rain-fall flowed into the streams, the remainder going off in evaporation or being used by plant life.

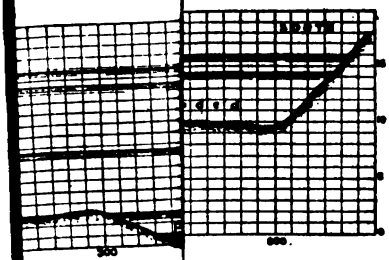
In answer to a question from Mr. Wm. M. Edwards, the author said that no municipalities, so far as he knew, had taken steps towards establishing record stations of their own for keeping records of rain-fall, etc.

Prof. McLeod

Prof. McLeod said that Mr. Breithaupt's paper recalled to him a very important discussion at the annual meeting of 1903. The Society had made some very good resolutions in regard to the matter of asking the Government to measure the flow-off, and a committee had been appointed for this purpose. There was certainly a large amount of work to be done, and it could only be accomplished by organized effort on the part of the Government. He suggested that Mr. Lea take the necessary steps to induce the Government to assume the charge of this important work, which would be of great value to engineers.

Mr. Lea

Mr. Lea replied that it had been proposed to prepare some kind of memorandum and submit it to the Council, which was to push



Cross-section

the matter with the Government, in order to have certain streams gauged and measured regularly every day for a long period of years. While this information might not be of much value for some time, it would be eventually, and unless the work was begun soon it would be impossible to obtain the information when it was needed.

Mr. Johnson suggested that the matter be looked into. Nothing could be better than a proper record of certain streams, and it would be well to bring the matter before the Society, and take some course of action in the matter. Mr. Johnson

PAPER No. 237.

MILITARY ENGINEERING:

Its History and Connection with Civil Engineering.

By Capt. T. E. Naish, R.E., M. Can. Soc. C. E.

Historical:—Military, Civil, and "Ornamental" Engineering.

Man was a fighter before he became an agriculturist or a manufacturer, and so military engineering preceded civil engineering, and has still retained (and always will retain) some of its primitiveness.

Indeed, between military engineering and civil engineering there is historically an intermediate stage which we may call "ornamental engineering,"—to this stage belong the Pyramids, the Colossus at Rhodes, Cleopatra's Needle, and the enormous monoliths in the Phoenician temple wall at Baalbec in Syria. Wherever we notice this stage of "ornamental engineering," we may infer a lengthy period of previous civilization, which will be confirmed by the researches of archaeology.

We know that Egyptian civilization had existed for a long time when the Great Pyramid was built by Cheops, though that event took place nearly 4,000 years B.C., because the art of that same period had long passed the barbaric state, and shows signs of elaboration; and the religion that brought the enormous granite sarcophagi of the underground temple of Serapis hundreds of miles down the Nile, was not that of a primitive people. It would seem that the ancient world had no call for utilitarian engineering, for the energies of the engineer in peace time were only turned to unproductive and monumental works.

Perhaps the earliest civil engineering works now in existence are ancient canals and irrigation works;—we read of a celebrated Chinese engineer named Yü who was engaged in canal building in B.C. 2,200, and we know that there were very ancient irrigation works in connection with the Nile and its annual flood.

Probably the oldest military engineering work now extant is the great wall of China; similar to it, but following thousands of years after, are the Roman walls built from sea to sea across the north of England, to keep off the invasions of the Picts and Scots.

The very traces of the greatest military engineering feats of old have from the nature of things disappeared, such as the bridge of boats built by Xerxes across the Hellespont, the damming of the River Euphrates at Babylon to effect an attack of the city along

the dried river bed, the ignition of the besiegers' ships at Syracuse with burning-glasses by Archimedes and his lifting of the same ships by huge cranes.

The earliest road making was for military purposes,—perhaps the best known (though not the most ancient) example of which is the Roman roads in Great Britain; the peculiarity of these roads is, that they run often in a perfectly straight direction for many miles, ignoring hills. They are still in many cases in use, and retain their ancient names, such as Watling Street, Fosse Way, etc.

As in the case of the Chinese and Egyptian civilizations, the first example of civil engineering on the part of the Romans took the form of hydraulic works and aqueducts, and are in many places still in existence.

But one might almost say that civil engineering is the growth of the last century;—up to that time the word "engineer" meant military engineer, and when Shakespeare said

" 'Tis sport to see the engineer, hoist by his own petard,"

it was not necessary for him to qualify the word.

The engineer in Shakespeare's time was engineer and artillerist in one,—he managed the engines of war, which then used gunpowder instead of the more primitive propelling forces of the catapult, and he blew in the gates of a town or castle with a petard instead of using the more primitive battering ram. In those days the word "artillery" was applied to the art of the archer, as will be seen in the authorized translation (date about A.D. 1600) of the Bible (story of David and Jonathan).

Likenesses and Contrasts in the Various Branches of Civil and Military Engineering.

In the enormous development of civil engineering during the nineteenth century, it was the steam engine that set the avalanche moving, gaining volume at every foot of its onward progress.

There has been no corresponding development of military engineering, but it has been rendered increasingly difficult to become a good military engineer. The military engineer must scan the whole field of hydraulic, railway, mining, electric, mechanical and sanitary engineering, and pick out from each branch what will be useful to him. He cannot afford to neglect any, and must be dependent on the specialist in each for the advancement of his own science, for though he may very often become a specialist himself, yet he must never neglect a knowledge of the other branches.

It is not, however, a case of being "master of all trades," for he need only know what of each trade is capable of military ap-

plication. To take an example:—Development in bridge building has scarcely affected the military art at all, which still remains primitive,—military bridges are almost entirely built of timber, rope and nails. It is true that the military engineer may be called upon to repair steel bridges or stone arches as in the South African war, but he does this primarily by erecting a temporary timber structure (completed in a few hours) and then proceeds more leisurely to a permanent repair if the proximity of the enemy permits. Boat bridging is almost entirely a military art, and a branch of the Royal Engineers called the "Pontoon troop" has this as its special occupation. Again, the destruction of bridges is a problem seldom faced except by the military engineer.

Of course, the functions of the civil and military engineer often overlap; principally in survey, in railway engineering, and in telegraphy.

For many reasons it may be convenient to carry out surveys by a military organization, as in the Ordnance Survey of the British Isles, the Survey of India, etc., and in some cases it may be absolutely necessary (as on a hostile frontier); but the methods and instruments employed by military engineers are almost exactly the same as those of civil engineers. It is convenient to build many railways on or close to the India frontier under military direction, and it was absolutely necessary so to build the railway from Cairo to Khartoum by which the Soudan was re-conquered; and here again the methods of military and civil engineer are the same.

As far as mechanical engineering is concerned, the military engineer takes a civil invention, such as the steam engine, oil engine, bicycle, motor car, and adapts it for military purposes; similarly with the lathe, shaping machine, drilling machine, etc., when applied to the manufacture of big guns and other military material.

The principles of sanitation are the same for the military engineer as for the civil engineer, but they have respectively to apply them to widely varying conditions, as will be seen by comparing the problems of water supply and disposal of refuse for an army of 30,000 men spread out for a variable period along, of a front of (say) 15 miles, and that for a similar number of inhabitants occupying permanent dwellings in a city.

Telegraph and telephone work (including wireless telegraphy) are almost exactly similar in their military and civil developments, civil inventions being applicable almost without adaptation to military requirements; but these sciences come in warfare under a large head which may be called "signalling,' and include the conveying of signals to a distance by semaphore, waving flags or flashing lights.

Electric lighting has been applied to harbour defence, search lights or fixed beams taking about 25 H. P. to run them, and also to siege operations.

Fortress Warfare From a Civil Engineering Point of View.

To turn from generalities to an actual example of modern warfare, let us imagine a staff of civil engineers, experts in all the branches, placed under the command of the general who is besieging Port Arthur, to give him the benefit of their advice. How can the fortress be reduced? First, the water supply may be cut off, and the railway rendered useless to the besiegers.

The throwing of explosives from a distance is now the work of the artillery, and the preparation of the sites for the guns requires more military knowledge than particularly scientific engineering.

But how to approach the chain of forts that protects the fortress? Can the engineers devise any means to protect the attacking troops from the hail of lead than mows them down in swathes like grass, even at a distance of 600 yards,—can shields be devised light enough to carry and yet impenetrable to bullets? Can any means be devised to cut those terrible wire entanglements? or to divert the electricity with which they are charged?

The fortress must be reduced in six months;—can tunnelling equipment be procured that can drive a tunnel 2,000 yards in that time and so enable a charge of explosive to be placed under a fort? Can any modern methods of excavating be employed? or are the pick and shovel to be the only tools for earthworks?

We can see how essential telegraphs and telephones would be to the conduct of the siege, and how ballooning would have a field of its own; but for the most part the refinements of civil engineering would be useless,—none the less there would be ample scope for the common sense, readiness of resouree, and energy which every successful civil engineer should possess.

Final Broad View of Subject,—the Patriotic Standpoint.

Taking a final view of the subject discussed, and from the broadest point of view, we find a close connection between civil and military engineering. Civil engineering has been defined as harnessing the great forces of nature for the service of man, and *military engineering may be defined as harnessing those great forces for the service of one's country.*

Looking at it from this point of view, can the building of the Siberian railroad be called distinctively either a military or civil operation? And can the building of the Canadian Pacific Railroad be considered entirely a civil operation? No more than a strike,

when organized labour enlists natural forces on its side against organized capital, can be considered a really peaceful operation.

There are more ways of conquering a nation than by actually shooting its inhabitants;—its food supply (for instance) may be cut off, and this may be done by apparently peaceful operations. In the establishment of the internal communications of Canada free from all warlike interruptions, that might disturb its supply of food, of fuel, and of raw material for manufacturers, are not the civil engineers of Canada doing the work that is most essential for the defence of their native land?

In such works as the new Transcontinental Railway, the Georgian Bay Canal, and railway communication to Hudson Bay, Canadian civil engineers are carrying out nothing less than the peaceful conquest of their own country.

DISCUSSION.

Mr. H. R. Lordly read some notes he had prepared on this subject, in which he stated that any engineer with good sense, judgment, and patriotism would make a good military engineer, as illustrated in the war between the Northern and Southern States, which was so successfully carried on, much to the astonishment of military experts of other countries. Mr. Lordly

A new corps had been organized recently in Canada, which would be of interest to the members of the Society, viz., the Intelligence Corps, directed by two members of the Society of Royal Engineers, the membership of which was made up largely from the Canadian Society of Civil Engineers. The chief work of this corps was to provide military engineers in time of war. There was great competition for admittance into this Corps of Guides, and no one was admitted unless he could be of use and could pass the required examinations. The Government, however, sought and would continue to seek the services of members of this Society.

PAPER No. 238.

AN ASPHALT PLANT FOR WALKS AND CROSSINGS IN SMALL CITIES.

By H. B. R. Craig, A. M. Can. Soc. C. E.

In dealing with this subject, the writer proposes to describe an asphalt plant operated by the city of Kingston for the past twelve years.

This plant occupies a space of half an acre in one of the corporation yards, but at the same time, should much asphalt work be done in any district of the city far away from the yard, the entire plant may be advantageously moved to a convenient place in that locality. A covered shed, 30 by 20 feet, serves as a protection to the plant proper, and the remaining space is used for storing the stock of asphalt, tar, and fuel, and for tarring the broken stone.

The plant consists of an asphalt boiler of 40 gallons capacity, a sand-heater with a surface of 100 square feet, and a mixing-board of about the same size. The sand-heater is simply a sheet-iron plate, half an inch thick, resting on four brick walls two feet high and one foot wide, enclosing an oven. The fuel is fed to the oven through a hole in one of the walls. The initial cost of the plant was $105.00.

In operating this plant the daily pay roll amounts to $12.74, and itemized is as follows:—

2 Labourers—Boiling Asphalt, heating sand, and mixing, @ $1.50	$3.00
1 Labourer—Boiling Asphalt, heating sand, and mixing, @ $1.57	1.57
1 Labourer—Preparing the foundation, @ $1.50	1.50
1 Labourer—Preparing the foundation, @ $1.35	1.35
1 Labourer—Laying and finishing the surface mixture, @ $1.57	1.57
1 Labourer—Laying and finishing the surface mixture, @ $1.50	1.50
1 Carter—Carting the mixture to the walk, @ $2.25	2.25
	$12.74

There is no charge made for superintendence, as the foreman of streets attends to that.

The cost of the various materials is as follows:—

Asphalt..	1.57	cents per pound.
Sand..	90.0	cents per cubic yard.
Cement..	170.0	cents per 350-lb. barrel.
Gravel..	75.0	cents per cubic yard.
Tar..	1.0	cent per pound.

The daily output of the above force is about 300 square feet of finished crossing or walk.

The following statement shows in detail the cost of laying 15,000 square feet of asphalt crossings during the year 1905:

Material	Cost in cts. per sq. ft.	Labor.	Cost in cts. per sq. ft.
Stone..	0.267	Boiling Asphalt and heating sand...	1.25
Asphalt..	3.690	Carting..	1.082
Cement...	0.080	Laying and finishing surface..	0.917
Fuel..	0.110	Preparing foundation.	1.020
Hardware...	0.015		
Tarred Gravel..	0.510		
Sand..	0.630		
	5.302		4.275

Total cost per square foot of crossing.. .. .. 9.577 cents.

It will be noticed that the charge for fuel is very small. That is due to the fact that the fuel is obtained from the old plank walks which are torn up when being replaced by new walks. The only charge, therefore, is that of cartage.

The cost of crossings is less than that of walks as the expense of preparing the foundation is a little more with the latter than with the former, and more tarred gravel is required in the case of the walks to give the surface mixture a firm base.

The manner of construction of the asphalt crossings is as follows:—

Surface Mixture.

(*a*) 270 pounds of Acme asphalt are heated to 300 degrees Fahrenheit and kept at that temperature for about two hours, being constantly stirred.

(*b*) 20 bushels of medium coarse sand, screened of all material ¼ of an inch and over, are heated to drive off the moisture.

(*c*) The asphalt and sand are then thoroughly mixed by hand on the mixing-board.

Laying on Macadam Roadways.

A furrow is picked up along the edge of the crossing so as to produce the desired camber and to prevent the wheels of vehicles from cutting into the asphalt. A load or two of tarred gravel in addition to this may be required along the length of the crossing.

The asphalt surface mixture is then laid on the foundation as prepared to a depth of two inches. It is well tamped and pounded along the edges and thoroughly rolled with a heavy two-man roller, the surface of the roller and the pounder being first well oiled so as to prevent the mixture from adhering to them. A thin coating of cement is then sprinkled over the wearing surface and wetted down, about one pound of cement being required for every ten square feet of crossing.

Should the crossing require to be used on the same day or if the work is done in very hot weather, some limestone screenings spread over it and well wetted down will act as a protection.

Asphalt walks are constructed in a similar manner, with the exception of the foundation course. The ground is cleared of all loose material and graded to a firm, even base, cinders well sprinkled and tamped being used to bring the walk to the required elevation. On the cinders is placed a 4-inch layer of tarred gravel. This course is pounded to give a firm, even bearing for the surface mixture, which is then laid as before.

On a heavily travelled street with the roadway abutting the walk, a concrete curb of the usual design is built in place along the outer edge of the walk. Wherever feasible, however, the usual custom is to arch the outside edge of the walk and tamp it well into a small furrow. In this way an almost vertical face may be produced. Limestone screenings may then be placed along this edge for backing. A 1 by 10 inch form properly braced is placed along the inside edge of the walk before construction and is usually left there.

A method sometimes used for the outside face is a 2 by 10 inch form braced by means of 4-inch cedar posts placed every six feet on the walk side of the form and driven one foot into the ground. This is not to be recommended as the posts will eventually be heaved up by the action of the frost, thus destroying the wearing surface, and the form soon rots out.

The life of the asphalt crossings is found to vary from ten to twenty years. This together with such a low initial cost renders them vastly preferable to plank crossings and even to many of the more expensive crossings, such as those built of concrete, brick, or stone. For example there are several crossings built of asphalt in Kingston which have outlasted the surfaces of heavy concrete crossings of the same age and two to three times the initial cost.

Another point in favor of asphalt for both crossings and walks is its elasticity, which when not too great is very desirable.

Several varieties of asphalt have been tried in this city, such as Trinadad Lake, Kiola, and Acme. The last brand is at present used and the mixture as given is found to be simple and to produce good results.

DISCUSSION.

Mr. Lordly — Mr. H. R. Lordly recommended that the author of the paper be asked to include in his charges the time for superintendence by the foreman, and also the actual value of the fuel, because, if the old planks were of value to the city for fuel, they should be charged to the plant and the city credited with the amount. By making this alteration, the paper would be of some value as a comparative statement.

Mr. Craig — Mr. Craig agreed that the foreman's time should be charged to the asphalt work. The charge would amount to 0.14 cents per square foot.

Mr. Goldmark — Mr. Henry Goldmark asked about the wearing quality of roadways built of asphalt, as compared with those built entirely of concrete, and said he would like to know if anyone present had had any experience in that line.

The question was why roadways of this class were not more general. He had read that concrete roads were commencing to come into use.

Mr. Craig — Mr. Craig replied that it was generally conceded that cement concrete roadways were inferior to those surfaced with asphalt. He could not name any municipality which had met with success in the operation of pavements of the former kind. The objections to cement concrete roadways were their friability on account of being so hard and unyielding; their extreme slipperiness, especially in wet and frosty weather; and their greater cost, as compared with a sheet asphalt or a bituminous concrete roadway. Cement concrete as a foundation for asphalt block and brick pavements had, however, proved a success.

Mr. Hannaford — Mr. Hannaford added that the concrete crossings in Kingston had not lasted as well as the asphalt. Crossings on Clarence street, at the corner of King and Ontario streets, had been in use for twelve years and the whole surface was chipped off, in some places to a depth of two or three inches. Asphalt crossings under the same conditions and at just as busy places seemed to have lasted much better.

MEMOIR OF JOSEPH TOMLINSON.

By WILLIAM P. ANDERSON and J. A. L. WADDELL.

There passed away on May 10th, 1905, at the ripe old age of 89, Joseph Tomlinson, at one time Lighthouse Engineer in the Marine Department of Canada, and later Bridge Engineer in the Department of Railways; who, although never a member of the Canadian Society, having retired from active practice of his profession soon after this Society was organized, was yet so well known and esteemed by the older generation of engineers, and did such good work for Canadian engineering, that it is eminently proper and appropriate that some record of his life and work should appear in the transactions of this national society of civil engineers; the more so, because Mr. Tomlinson was of so modest and retiring a disposition that he never sought publicity for himself or his work, and has, consequently, been forgotten by many of our younger members.

He was born in Ruskington, Lincolnshire, on 22nd June 1816, being one of a family of fourteen children of Joseph and Ann (Shearwood) Tomlinson, his father being a land-owner who farmed extensively. As a boy he was considered dull, and disappointed his parents so much that they early removed him from school, where the old-fashioned classical curriculum did not appeal to his mathematical instincts, and apprenticed him to a cabinet-maker at Newark. But, as often happens, they misunderstood his capabilities. Long before he was out of his time, he was acknowledged to be a better workman than his master, and during the seven long years of his apprenticeship, he made opportunities, after the long hours in the workshop, to study mathematics and draughtsmanship, and with the help of a Mechanics' Institute, laid the foundation of those habits of hard work, study and general reading, that he kept up to the day of his death. The thorough training in framing and wood-fitting he received under the old system of long apprenticeship undoubtedly stood him in good stead throughout his entire professional career, for he was often called upon to supervise the fieldwork of large constructions. On such occasions there was no detail of the actual construction work that he could not undertake with his own hands—and powerful hands they were, for when in his prime he possessed a wonderful physique. This ability to do, as well as to direct manual and skilled labour was a great advantage, in that it

gained for him the respect, as his kindly and genial nature gained the esteem, of all his workmen.

During his youth, England was in the throes of the great social revolution that culminated in the Chartist riots, and Mr. Tomlinson knew and listened to the teachings of the great reform leaders, and had impressed on his youthful imagination the duties of self-denial, of work for the betterment of his fellows; in short, of socialism, in the best sense of the word; ideals to which he remained constant through life.

In 1840, when he was 24 years of age, Mr. Tomlinson came to America and settled in New Milford, Conn. Here he found the practice in his own trade so radically different from the thorough methods in which he had been trained that he drifted into other branches of the work, and soon found his vocation in bridge building, through the following incident: On inspecting a railway bridge under construction, he confided to his friend, Rev. Dr. Noah Porter, afterwards President of Yale College, his opinion that a miscalculation had been made regarding its resistance and weight, and when his judgment was justified by the subsequent partial collapse of the bridge, Mr. Tomlinson was employed to repair it, and acting on Dr. Porter's advice, turned his attention to engineering, subsequently designing and building a great many bridges on the Housatonic Railway extension, the Whitehall and Rutland Railway, and the Harlem Railway extension.

The first bridge he ever planned and built, as a contractor, was a bridge at Pittsfield, Conn., in 1844, which is still standing.

He prepared plans for and financed the Whitehall tunnel, after its construction had been attempted and practically abandoned because of the inroads of the quicksand. On the plans of this tunnel, he worked without a single hour's cessation for three days and three nights, and this power of concentration and prolonged work was characteristic of the man.

From 1854 to 1862 Mr. Tomlinson was employed by the New Brunswick Government constructing bridges, and it speaks well for the honesty of his work and materials that after half a century most of these wooden bridges are still standing.

The only bridge he built that fell was a bridge over the River St. John at Grand Falls, N.B. Into this bridge he was induced to incorporate Nova Scotia iron that had not been tested. On the completion of the bridge it was opened with some ceremony, and carried safely a multitude of people and a procession of sleighs, but the next day, under the strain of 30° of frost, it fell when loaded with only a single team. This bridge was rebuilt by Mr. Tomlinson, as a suspension bridge, with tested materials, and is still standing. Although the Government assumed full blame for the catastrophe,

it is typical of Mr. Tomlinson that he never put in a bill and was never paid for his work on the fallen bridge.

The first bridge he built in New Brunswick was the Hammond River Bridge, still in use. The best known of his New Brunswick bridges is the suspension bridge over the falls in the city of St. John. In later years he was temporarily borrowed from his lighthouse work to put in for the I. C. R. the foundations of the railway bridges over the Miramichi River.

From New Brunswick, Mr. Tomlinson moved to Ohio, in 1862, where he was connected with the Lake Shore and Michigan Southern Railway, and later supervised some important structures for the city of Cleveland, including the building of a large market house.

Mr. Tomlinson was called to Kansas City, Mo., in 1867, by Mr. Octave Chanute, to act as engineer of the superstructure of the Hannibal bridge across the Missouri River, the first permanent bridge to cross that great stream. He designed the superstructure, and after the channel piers had been washed out, was put in charge of the foundations, replaced them from original designs and completed the bridge with perfect success.

When the Honourable Peter Mitchell was organizing the Marine Department after Confederation and wanted an engineer who could undertake the construction of a large number of lighthouses expeditiously and economically, he bethought him of the man whom he had known while in the Provincial Government, and who had served his native Province so successfully as a worker in wood, and invited Mr. Tomlinson to return to Canada, which he did, remaining in charge of lighthouse construction during the growing time between 1870 and 1880; and although his buildings are all cheap wooden structures, they were efficient and were erected with marvelous rapidity and economy, considering the great extent of coast to be covered and the difficulty of access to many of the sites. It was while he held this position of General Superintendent of Lighthouses that the writers of this memoir had the privilege of becoming acquainted with him, by working under him, and are, therefore, in a position to appreciate the great work he did in that office. The Department, when he joined it, was absolutely new and had to absorb and assimilate the heterogeneous practices of a dozen Lighthouse Boards. Designs had to be evolved without previous records for consultation; and the amount of work required could have been accomplished only by a man of first-rate practical ability. Many of Mr. Tomlinson's towers still guard the approaches to the Dominion and are beautiful examples of heavy braced framing. The two octagonal lighthouses on Sable Island, erected in 1873, and the

tall tower on Greenly Island, may be quoted as examples of his best work.

He greatly improved the illuminating apparatus that he found in use, substituting petroleum for the Colza and seal oils previously used, devising improved burners, verifying each step of his progress by photometric and laboratory tests, and personally instructing the lightkeepers in the proper methods of getting the best results from the apparatus put in their charge.

In 1880, Mr. Tomlinson was transferred to the Department of Railways, to design the wooden truss bridges and trestles for the Government sections of the Canadian Pacific Railway, and got out a set of standard designs, which were used throughout the work.

In 1882 he was sent by the Canadian Government to England, to supervise the manufacture of the metal-work for the long cantilever bridge that was to span the Fraser River on the main line of the Canadian Pacific Railway. Later on he superintended the erection of this noted structure. This was his last considerable engineering work, and in 1885 he accepted superannuation and settled in Cedar Rapids, Iowa, to be near a large farm that he had bought in that neighborhood many years previously, and which is now managed by his eldest son. He remained at Cedar Rapids, with his wife and youngest daughter, until his death, which occurred very suddenly, while he was engaged in his favorite recreation of gardening.

In 1845 Mr. Tomlinson married Miss Anna R. Northrup, of New Milford, Conn., and three daughters were born to the marriage, one of whom is still living. Mrs. Tomlinson died in 1852, and in September, 1853, he married Miss Sarah A. Wyles, of Lincolnshire, England, by whom he had five children, four of whom, with his wife, survive him. One of his sons, Mr. A. T. Tomlinson, is a member of our Society.

Mr. Tomlinson's principal characteristics as an engineer were extreme thoroughness in detail, neatness of execution, great persistency, and absolute honesty. He did personally a great deal of draughting on his various designs, and very few draughtsmen have ever equalled him in neatness of execution and fineness of work.

One of the main reasons for Mr. Tomlinson's great success as an engineer was the love he had for his work. He laboured for the work's sake, and not merely for the compensation received, a fact which was often taken advantage of by those who employed him.

There was nothing to which he looked back with greater satisfaction than to the difficulties in construction he had successfully overcome. He had absolute faith in his own ability, notwithstanding which he was always noted for his extreme modesty. He was

ever ready to acknowledge merit in others; and had a most decided hatred for everything that tends to give one man an unfair advantage over another.

His principles gave him great influence over his workmen, many of the best of them following him from one job to another; and in every way he endeavoured to benefit them, signing the temperance pledge for the sake of example, establishing reading rooms for them, and continually striving to elevate their minds and improve their material condition.

As a bridge engineer, he was far in advance of his age, and worked out his designs from carefully-calculated strain sheets, when most bridges were being erected by rule of thumb. He retained his mental activity up to the day of his death; and during the last months of his life was engaged in evolving a design for a very long suspension bridge, in connection with which he took out three patents. Despite his great age, the drawings for this bridge were essentially as fine as those he made during the prime of his life, and are now being used as models of draughtsmanship for young engineers.

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